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FISH AND WILDLIFE SERVICE

UNITED STATES DEPARTMENT OF THE INTERIOR
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THE PROGRESSIVE FISH-CULTURIST

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FISHING IN THE TAILWATERS OF T.V.A. DAMS

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Tennessee Valley Authority
Norris, Tennessee

THE TVA RESERVOIR SYSTEM provides three general types of fish habitat: storage reservoirs, mainstream reservoirs, and the tailwaters below dams. Although all three types provide an abundance of fishing, none is more popular, more heavily fished, or yields more fish per trip than the tailwaters on the main Tennessee River. These fast, turbulent waters below the dams can be credited with about 35 percent of the estimated 2 million fishing trips per year on all TVA waters. Tailwater fishermen account for approximately 52 percent of the 7-million-pound harvest from the entire TVA system.

These fast, well-oxygenated waters attract many species of fish, including white bass, crappie, catfish, yellow bass, drum, buffalo, mooneye, and skipjack. Black bass, walleye, and sauger are also present in considerable numbers in some tailwaters.

For the past 6 years TVA Public Safety officers have made daily counts of fishermen below eight mainstream dams. At one, Kentucky, counts have been made for only 5 years. At Douglas, a tributary dam, counts have been recorded for 4 consecutive years. Fishermen in boats and on the banks are counted once each morning and twice each afternoon, usually at 1 o'clock and at 6 o'clock. At the scheduled hours, 7 days a week, the officers count the fishermen visible from the top of the dam and record the bank and boat fishermen separately. In earlier studies bank fishermen were found to average about 4.1 hours per trip and boat fishermen about 5.0 hours. On this basis, the morning count and the highest afternoon count are combined to give the total number of individual fishing trips per day.

These estimates are thought to be conservative because (1) considerable night fishing is not recorded, (2) the limited number of winter fishermen are most active in the middle of the day and escape counting, and (3) during the season of most intense fishing the continuous movement of fishermen might cause a lower than actual count. One counterbalancing influence, no doubt, is the tendency of some trips to extend through more than one counting period.

We believe the estimates are relatively accurate. The method of collecting the information has been reasonably consistent throughout the period, and the results may be reliably compared. The extent, variation, and trends of fishing are clearly shown; and the importance of tailwaters in a multipurpose reservoir system is established beyond a doubt.

In this discussion "fishing trip" means one person on one trip. The "years" are fiscal years, beginning July 1 of the previous calendar year. No statistical validation of these data or of collection methods has been attempted.

MAINSTREAM TAILWATERS

Except for a slight decline in total fishing trips in 1951, tailwater fishing trends have been upward, showing an all-time high of 810,333 for fiscal year 1953 (see table 1). This is more than double the 1947 estimate of 339,000. During the

TABLE 1.--Number of individual fishing trips in the mainstream tailwaters below TVA dams, by months in fiscal year 1953, and by years, 1946-1953

Month	Fort Loudoun		Watts Bar		Chickamauga		Hales Bar		Guntersville	
	Boat	Bank	Boat	Bank	Boat	Bank	Boat	Bank	Boat	Bank
1952										
July	715	1,497	1,424	2,551	1,068	3,548	599	6,667	2,813	9,904
August	1,028	2,396	1,513	2,933	540	2,681	629	4,243	3,469	12,282
September	986	2,407	1,137	1,892	518	2,410	465	2,914	4,840	13,055
October	891	2,931	872	1,525	639	3,165	384	1,874	2,921	8,112
November	684	1,550	487	1,392	451	2,321	901	2,142	2,026	5,087
December	277	531	109	773	138	1,270	516	1,515	754	2,779
1953										
January	507	1,257	434	1,793	207	1,154	520	1,626	804	4,440
February	906	2,407	568	2,302	158	1,476	457	1,461	1,067	7,499
March	1,995	4,380	867	4,149	447	3,461	383	2,606	1,998	15,165
April	2,235	3,650	881	3,829	146	3,645	673	4,021	3,277	17,351
May	3,003	5,663	1,408	4,772	601	5,524	1,295	8,635	4,819	16,173
June	2,024	3,019	894	2,026	825	4,253	917	4,702	2,868	10,491
Total	15,251	31,688	10,594	29,937	5,738	34,908	7,739	42,406	31,656	122,338
Percentage	32	68	26	74	14	86	15	85	21	79
1952-53	15,251	31,688	10,594	29,937	5,738	34,908	7,739	42,406	31,656	122,338
1951-52	10,193	23,178	10,294	25,075	6,210	31,858	3,610	28,150	19,908	99,391
1950-51	13,411	32,869	9,665	29,710	3,936	22,548	2,137	20,473	16,036	88,170
1949-50	20,732	37,996	13,411	36,102	3,057	22,117	3,231	29,201	22,442	125,743
1948-49	11,579	17,999	14,700	35,295	4,575	31,722	5,362	24,896	25,523	141,187
1947-48	5,322	8,635	11,914	28,786	3,599	26,221	3,451	21,134	12,742	84,690
1946-47	5,003	7,285	10,284	23,691	3,239	26,534	3,981	13,408	9,224	63,616
Grand total	81,491	159,650	80,862	208,596	30,354	195,908	29,511	179,668	137,531	725,135
Percentage	34	66	28	72	13	87	14	86	16	84

TABLE 1.--Number of individual fishing trips in the mainstream tailwaters below TVA dams, by months in fiscal year 1953, and by years, 1946-1953--Continued

Month	Wheeler		Wilson		Pickwick		Kentucky		Total		Grand Total
	Boat	Bank	Boat	Bank	Boat	Bank	Boat	Bank	Boat	Bank	
1952											
July	5,623	5,573	2,335	457	7,564	12,693	11,371	13,175	33,512	56,065	89,577
August	5,010	4,118	2,302	330	5,195	8,158	9,448	13,244	29,134	50,385	79,519
September	5,499	3,970	2,466	478	4,280	6,118	6,729	10,878	26,920	44,122	71,042
October	4,151	3,159	1,612	401	3,887	6,275	7,199	12,508	22,556	39,950	62,506
November	1,293	1,940	2,999	1,229	3,814	5,672	2,150	3,576	14,805	24,909	39,714
December	245	627	1,367	268	3,096	9,015	674	1,585	7,176	18,363	25,539
1953											
January	283	687	782	227	1,769	6,016	248	1,848	5,554	19,048	24,602
February	474	762	1,151	224	2,302	8,192	124	3,452	7,207	27,775	34,982
March	2,188	5,571	1,793	540	2,319	10,999	672	8,689	12,662	55,560	68,222
April	5,012	6,634	3,555	626	3,027	11,967	2,661	21,325	21,467	73,048	94,515
May	7,526	7,260	5,494	695	6,638	15,949	6,757	30,218	37,541	94,889	132,430
June	5,764	4,638	4,169	319	7,184	11,276	9,510	12,806	34,155	53,530	87,685
Total	43,068	44,939	30,025	5,794	51,075	112,330	57,543	133,304	252,689	557,644	810,333
Percentage	49	51	84	16	31	69	30	70	31	69	
1952-53	43,068	44,939	30,025	5,794	51,075	112,330	57,543	133,304	252,689	557,644	810,333
1951-52	42,092	36,122	25,672	4,379	39,357	79,454	60,660	120,309	217,996	447,916	665,912
1950-51	33,852	24,179	18,074	4,991	43,561	81,038	63,780	99,091	204,452	403,069	607,521
1949-50	29,141	21,681	21,965	5,937	46,526	75,925	63,014	88,469	223,519	443,171	666,690
1948-49	31,381	11,904	27,473	7,915	47,702	73,857	61,809	82,175	230,104	426,950	657,054
1947-48	21,512	4,335	15,370	7,525	49,255	72,702	23,573	55,815	146,738	309,843	456,581
1946-47	22,481	12,742	10,960	6,777	34,657	52,294	-	-	-	-	-
Grand total	223,527	155,902	152,539	43,318	312,133	547,600	330,379	579,163	1,275,498	2,588,593	3,864,091
Percentage	59	41	78	22	36	64	36	64	33	67	

past fiscal year, 31 percent of the angling was by boat and 69 percent was from the bank. This ratio follows closely the 7-year means of 33 percent by boat and 67 percent from the bank (see table 2).

Beginning in 1950, heaviest angling pressure shifted from Guntersville Dam tailwater in Alabama to Kentucky Dam tailwater in Kentucky. The figures for the top three tailwaters for the 1953 fiscal year are as follows:

State	Tailwater	Number of fishermen (boat & bank)
Kentucky	Kentucky Dam	190,847
Tennessee	Pickwick Dam	163,405
Alabama	Guntersville Dam	153,994

Angling from the bank predominates over angling by boat at seven of the nine mainstream tailwaters. At Wilson and Wheeler Dams the reverse is true because of general inaccessibility.

The decrease in the number of fishermen in fiscal year 1951 is attributed to restrictions imposed by (1) the declaration of a national emergency in December 1950 and (2) installation of additional turbines at Guntersville, Wheeler, and Pickwick Dams, and a bridge on Kentucky Dam.

Sport Fishing

A creel census was taken at Guntersville Dam tailwater, one of the most heavily fished, for the 5 fiscal years 1947-1951. It ran 5 days a week in the spring and 1 week per month at all other times except midwinter, when it was discontinued because of relatively light fishing. This census was discontinued at the end of the 1951 fiscal year because of insufficient funds but was resumed during April, May, and June, 1953. The catch increased from 313,910 pounds in fiscal year 1947 to 1,021,581 pounds in fiscal year 1950. In 1951 the catch decreased to 527,455 pounds (see table 3). This decrease in total pounds harvested and average catch is ascribed to (1) construction activities and security regulations, (2) severe winter weather--coldest in 4 years, and (3) a probable natural drop in fishing intensity. The catch per trip increased from 4.5 pounds in 1947 to 6.9 pounds in 1950 and then dropped to 5.1 pounds in 1951, along with a drop in fishing intensity of 43,979 fishing trips.

Estimates computed (see table 3) from the total fisherman count and mean catches of the census sample show that the 5-year annual yield from Guntersville Dam tailwater ranged from about 3 hundred thousand pounds to better than 1 million pounds. Parallel data from other tailwaters are not available for comparison; however, a spring census was taken on the Watts Bar tailwater in 1953 (see table 4). During April, May, and June, 13,810 fishing trips were recorded (about one-third of the total annual count for this tailwater). Judged on the basis of the creel sample means, fishermen took 67,669 fish weighing 42,811 pounds during the 3-month period.

Commercial Fishing

Commercial fishing immediately below dams is generally prohibited, or at least restricted, by State law. The main purpose of such regulations is to prevent commercial fishing gear from physically interfering with the intensive sport fishing. The overwhelming importance of the sport fishing in our present economy appears to justify such action.

The value of the sport fishing in the Tennessee Valley has been estimated at 10 to 12 million dollars per year in terms of total business generated. Commercial fishing, on the other hand, runs into only about half a million dollars a year.

Rate of Harvest

Although the various States impose no closed season on TVA mainstream reservoirs, there is no evidence of overharvesting. During the past 8 years, 14,486 fish have been tagged on Wheeler and Guntersville reservoirs. Through February 1953, only 313 tags (2.2 percent) have been returned or reported.

TABLE 2.--Percentage of boat and bank fishing in the mainstream tailwaters below TVA dams, by years, 1947-1953

Year	Fort Loudoun		Watts Bar		Chickamauga		Hales Bar		Guntersville	
	Boat	Bank	Boat	Bank	Boat	Bank	Boat	Bank	Boat	Bank
1952-53	32	68	26	74	14	86	15	85	21	79
1951-52	31	69	29	71	16	84	11	89	17	83
1950-51	29	71	25	75	15	85	9	91	15	85
1949-50	35	65	27	73	12	88	10	90	15	85
1948-49	39	61	29	71	13	87	18	82	15	85
1947-48	38	62	23	77	12	88	14	86	13	87
1946-47	41	59	30	70	11	89	23	77	13	87
Grand percentage (7 years)	34	66	28	72	13	87	14	86	16	84

Year	Wheeler		Wilson		Pickwick		Kentucky		Grand percentage[1] all tailwaters (7 years)	
	Boat	Bank	Boat	Bank	Boat	Bank	Boat	Bank	Boat	Bank
1952-53	49	51	84	16	31	69	30	70		
1951-52	54	46	85	15	33	67	34	66		
1950-51	58	42	78	22	35	65	39	61		
1949-50	57	43	79	21	38	62	41	59		
1948-49	72	28	78	22	39	61	43	57		
1947-48	83	17	67	33	40	60	30	70		
1946-47	64	36	62	38	40	60	-	-		
Grand percentage (7 years)	59	41	78	22	36	64	36	64	33	67

[1] Grand percentage obtained by using total number of boat and bank fishermen for 7-year period (see table 1) in all tailwater areas except Kentucky Dam tailwater, where figures are available for only 6 years.

Fishways

TVA dams do not have fish ladders. Such structures, if effective, would be detrimental to fishing in the Valley. The dams serve as barriers to the upstream movement of warm-water fishes, concentrating them and facilitating the harvest.

TRIBUTARY TAILWATERS

Most tributary tailwaters provide only a limited amount of fishing. In contrast to mainstream reservoirs, storage or tributary reservoirs stratify in summer and their turbine discharges are relatively cold throughout the year. This limits the concentration of warm-water fishes in these areas.

Within the past 3 years, however, the Tennessee Game and Fish Commission and the North Carolina Wildlife Resources Commission have experimentally stocked several of these waters with trout. The success, though variable, has been very encouraging. In addition to experimental stocking, the Tennessee Game and Fish Commission initiated a Dingell-Johnson project to study and appraise several tailwaters that appear suitable for trout.

Fishermen have been counted on only one tributary tailwater--Douglas. Fishing

TABLE 3.--Fish catch in Guntersville Dam tailwater by months, fiscal year 1951, and summary of annual catches, 1947-1950

Month	Number of fishing trips	Catch per trip[1] Number	Catch per trip[1] Pounds	Total number of fish	Total catch pounds
1950					
July	18,338	7.5	4.5	137,535	82,521
August	16,856	6.7	5.4	112,935	91,022
September	10,293	6.1	7.3	62,787	75,139
October	7,179	6.2	4.7	44,510	33,741
November	2,270	2.5	2.0	5,675	4,540
December	1,253	2.5	2.0	3,132	2,506
1951					
January	1,798	2.8	1.7	5,034	3,057
February	2,565	6.8	3.4	17,442	8,721
March	6,428	3.8	1.5	24,426	9,642
April	8,045	4.4	4.4	35,398	35,398
May	15,204	9.1	6.4	138,356	97,306
June	13,977	8.6	6.0	120,202	83,862
Total and average[2]	104,206	6.8	5.1	707,432	527,455
1950	148,185	7.0	6.9	1,039,149	1,021,581
1949	166,710	7.5	5.4	1,242,920	895,934
1948	97,432	7.2	5.0	699,192	487,160
1947	72,840	6.2	4.5	455,075	313,910

[1]Averages based on 1,872--creel census records for the 12-month period. Mean weights based on the actual weighing of 14,208 fish.

[2]Averages weighed according to fishing intensity.

TABLE 4.--Species composition of catch, Watts Bar tailwaters, April, May, and June, 1953

Species	Number	Weight	Percent of total number	Percent of total weight	Trips
Largemouth bass	101	78.3	0.8	0.9	
Smallmouth bass	39	25.9	.3	.3	
Spotted bass	10	6.0	.1	-	
Crappie	741	399.9	5.6	4.8	
Walleye	10	7.6	.1	-	
Sauger	1,645	1,108.9	12.6	13.2	
White bass	2,469	1,733.2	18.8	20.7	
Drum	6,469	2,858.4	49.4	34.2	
Catfish	253	300.7	1.9	3.6	
Bluegill	518	133.4	3.9	1.6	
Rock bass	3	.7	-	-	
Carp	809	1,679.4	6.2	20.0	
Miscellaneous[1]	28	36.9	.2	.4	
Total	13,095	8,369.3	99.9	99.7	
Total trips					2,696
Average catch	4.9	3.1			

[1]Skipjack, redhorse, etc.

TABLE 5.--Number of fishing trips in the tailwaters below Douglas Dam, fiscal year 1953, and annually, 1948-1953

Period	Boat	Bank	Totals
1952			
July	536	5,072	
August	403	5,080	
September	310	3,927	
October	493	3,967	
November	189	3,589	
December	82	1,763	
1953			
January	91	1,959	
February	222	4,534	
March	548	9,172	
April	1,085	9,841	
May	909	6,852	
June	702	4,754	
Total (1953)	5,570	60,152	65,722
Total (1952)	3,885	43,587	47,472
Total (1951)	4,194	39,824	44,018
Total (1950)	6,572	61,295	67,867
Total (1949)[1/]	3,833	32,552	36,385
Total (1948)[1/]	2,804	17,612	20,416

[1/] Season closed April 1 to May 29, incl.

is perhaps more extensive here than in other tributary tailwaters. In 1953, this tailwater supported 65,722 fishing trips (see table 5). In 1948 and 1949, State regulations prohibited fishing these waters during April and May. Table 5 shows that when these regulations were removed in 1950, the number of fishing trips rose abruptly.

Eschmeyer and Miller[1/] judged that fishing on all other tributary tailwaters was about equal to that at Douglas. If this observation is reasonably correct, all tributary tailwaters combined supported a total of about 130,000 fishing trips in 1953.

[1/] Eschmeyer, R. W., and Miller, L. F. Fishing in TVA tailwaters. Tennessee Valley Authority. September 1949.

TABLE 6.--Recreational drownings in the TVA reservoir system, 1947-1952[1/]

Fiscal year	Total drownings	Drownings in tailwaters			
		Powerhouse	Spillway	Lock	Total
1947	41	1	3	-	4
1948	57	-	2	-	2
1949	49	2	6	-	8
1950	72	2	5	1	8
1951	51	-	6	-	6
1952	51	4	-	-	4
Total	321	9	22	1	32

[1/] Data provided by Safety Branch, TVA Division of Health and Safety.

DANGERS INVOLVED

Boat fishing in fast, turbulent tailwaters or in any similar waters can be hazardous. Failure to observe warning signs and the violation of the basic rules of water safety have contributed to a number of drownings below dams. In table 6 are listed drownings in tailwaters and total drownings in the entire TVA system for the fiscal years 1947-1952. The total, 321, includes accidental recreational drownings only. Of this number, 32 (9.9 percent) occurred in tailwaters: 9 in turbine discharge waters, 22 in spillway waters, and 1 in lock waters.

During this same period, 1,044,097 boat fishing trips were recorded for these waters. In other words, the 6-year average is 1 drowning for each 32,628 boat fishermen. In fiscal year 1952, the ratio was 1 drowning for each 54,499 boat fisherman. Though tailwaters probably have fewer drownings than reservoirs on a total recreational man-day-use basis, the loss of anglers may be greater in tailwaters.

The TVA Interdivisional Water Safety Committee and the Tennessee and Cumberland Valleys Water Safety Congress, through their various educational activities, may eventually reduce the number of drownings in tailwaters.

WEST VIRGINIA'S ELECTRICAL FISH-COLLECTING METHODS

George D. Holton and Carl R. Sullivan, Jr.
Conservation Commission of West Virginia
Charleston, West Virginia

INCLUDED AMONG THOSE who have described electric shocking equipment for stream work are Haskell (1940), Shetter (1947), Funk (1949), Rayner (1949), and several Canadian workers (Canadian Fish Culturist 1950). Electrical fish-collecting methods used in West Virginia are modifications of basic methods developed by earlier workers. West Virginia's methods are presented in the hope that they will contribute to progress being made in the development of more efficient methods for studying fish populations.

The work described was performed between September 1952 and February 1953 in connection with a project which was set up to investigate the possibility of increasing smallmouth bass populations by either eliminating or reducing populations of less desirable species.[1/]

The main work was on the Lost River in West Virginia's eastern panhandle. Unusually low water conditions prevailed during the fall when the area was studied. The river's flow at this time was about 17 cubic feet per second. Although little water was going over the riffles, there were still many pools one-fourth mile or more long, up to 100 feet wide, and up to 10 feet deep. The average stream width was 54 feet. The bottom was predominantly rocky. In all, 10 study sections comprising about 3.5 miles of the 26.5-mile river were covered in the shocking operations. Water temperatures were usually lower than 65° F. A water sample taken on February 17, 1953, had a hardness of 36 p. p. m. (as $CaCO_3$).

ALTERNATING-CURRENT EQUIPMENT AND METHODS

Alternating current was mainly used, as a direct-current generator was not procured until most of the work described had been accomplished. Two A. C. units (60-cycle) were on hand. One was a 350-watt Onan generator; the other, a 2,500-watt Leland generator. They were rated at 115 and 120 volts, respectively; however, both were speeded up to give voltages estimated to be between 180 and 200. No rheostats or transformers were used with the equipment described in this paper.

Parallel-Wire Electrodes

When conventional paddle-shaped electrodes are used in shocking, a limiting factor in wide streams is the maximum distance that the electrodes can be kept apart and still have sufficient voltage gradient in the electric field to paralyze the fish. In an effort to overcome this limitation, two bare-wire electrodes were stretched across the stream, parallel to each other and 6 to 8 feet apart. They were kept close to the bottom and moved slowly upstream or downstream through

1/This work undertaken with Federal aid to fish restoration funds, Dingell-Johnson Project Number W. Va. F-1-R-2.

the study area (figure 1). This arrangement allowed full coverage of the stream width (up to 50 feet), while at the same time the electrodes remained within effective distance of each other. In sections where they could be used, these electrodes proved superior to the paddle-type. The electric field covered a much greater area, especially upstream and downstream, making it practically impossible for fish to "run" through and escape. Also, the lines of flow of the electric current were parallel to the stream flow. As fish generally orient themselves with their heads upstream, this allows electric current to pass lengthwise through their bodies. McMillan (1929) showed that the amount of shock received is proportional to the distance the current travels through the fish. Thus a fish receives more shock if a current passes through him lengthwise rather than crosswise.

Flexible 12-gage copper wire was used for the parallel-wire electrodes. Wire made of a few (6) heavy strands proved far more durable than wire made of many fine strands. A wooden handle, 5 feet long, was attached to each end of each wire. Two 50-foot wires could be managed by two men, one at each bank, if the bottom was fairly free from obstruction. Longer wires would require a man at each end of each wire. Two or three more men were needed to collect fish. Excess wire was wrapped--automatic reels would greatly facilitate this operation--onto the handles. The handles (with wires attached) were used as electric probes for collecting fish from undercut banks, roots, etc. Each bank was shocked separately in stream sections wider than 50 feet. Depths up to 7 feet were efficiently shocked by this method. It was not tried in deeper water.

Alternating current for these electrodes was supplied by the 350-watt Onan generator. It was carried in a shallow-draught aluminum boat pulled by one of the men handling wires.

Modified Funk Seine

For wide pools a modification of Funk's (1949) electric seine was used (figure 2). A modification had previously been used by Joeris (1949) in Kentucky and by Surber and Seaman in West Virginia.[1/] Surber and Seaman's equipment was altered for use in this study. The basic unit was a 12-gage, 2-wire, rubber-insulated cable to which bare 12-gage copper drop wires 5 feet long were attached. The cable was kept at the surface by floats. The drop wires were spaced at 4-foot intervals, and connections to the main cable were alternated between the black and white wires so that at any instant every other drop wire was positive while every second one was negative. Two such cable units, each 75 feet long, were used. They were stretched across the stream, parallel to each other and 5 to 8 feet apart, and were plugged directly into the generator, which was in the aluminum boat at one shore. The distal ends of the cable units were separated by a wooden spreader pole. A rope attached to the boat and another rope attached to the spreader pole were used by a man on each bank to pull the electric seine upstream or downstream.

The largest pool studied on Lost River had widths up to 125 feet and depths to 10 feet. It was successfully shocked with this equipment. It is believed that by lengthening the cable units, much wider streams could be accommodated. The main difficulty was that of collecting stunned fish from the bottom in 7 to 10 feet of water. An annoyance was the occasional jamming of drop wires between boulders.

The use of the two parallel cable units across the river was found to be an improvement over the use of units in the conventional single line. Fish were frequently able to make a dash and "run" through the narrow field set up by the single line but were only rarely able to "run" through the double line. The feasibility of having the drop wires of each cable unit connected in parallel and the

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[1/] Surber, E. W., and Seaman, E. A. Fish population studies with an electric seine in the South Branch of Potomac and Cacapon Rivers, West Virginia. Typewritten report, 1950.

(Above)

FIGURE 1.--Parallel-wire electrodes being used on Lost River.

(Right)

FIGURE 2.--Modification of Funk seine in use on Lost River.

(Photos by C. B. Bishoff)

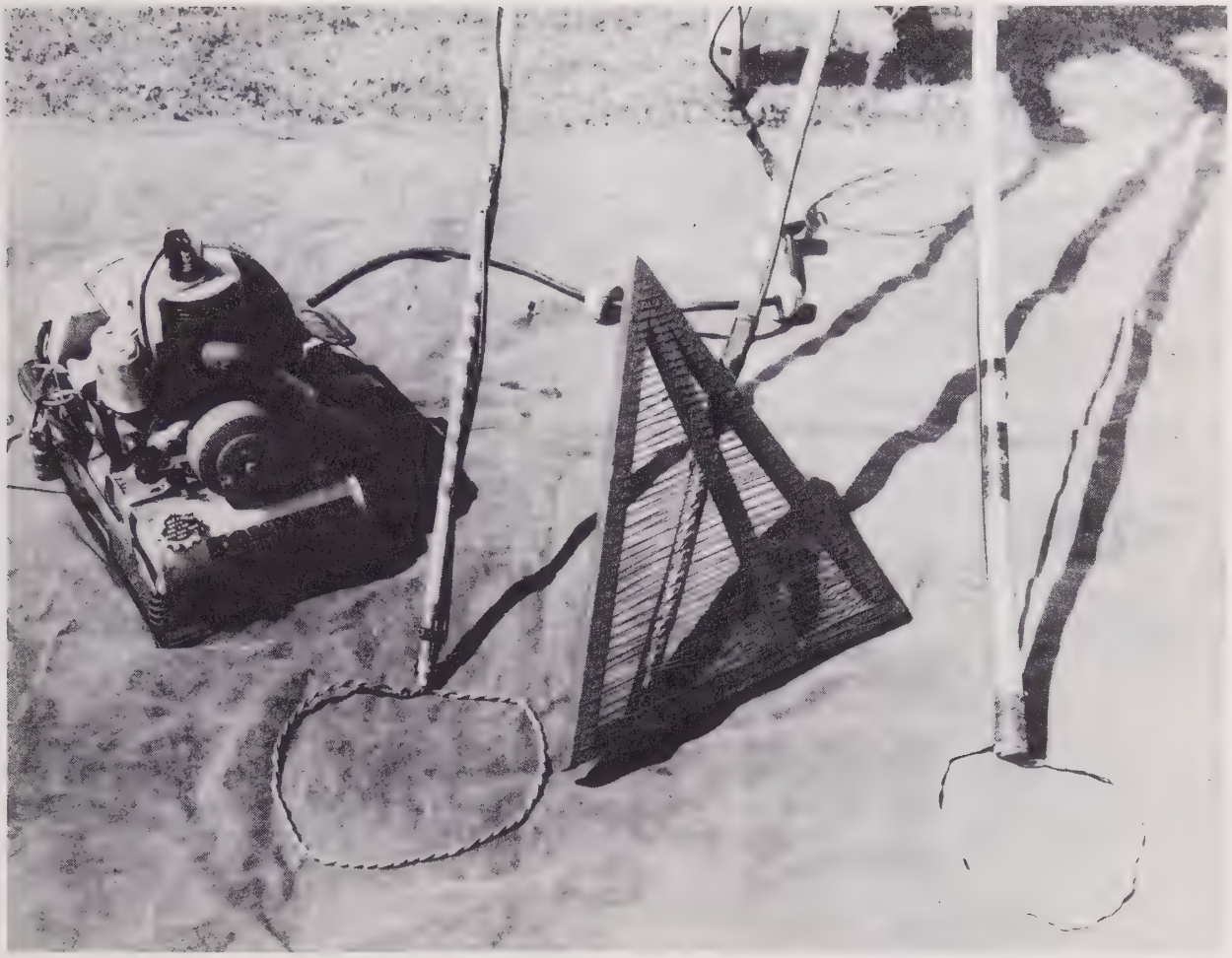

FIGURE 3.--Paddle-type electrodes and direct-current generator.

two cable units opposite in polarity was not tested.

The method described usually required a crew of six men and three boats. Two men, one on each shore, pulled the electric seine along the stream; a safety man rode in the boat with the generator to shut it off in emergencies; and three men collected fish from the other two boats.

The 2,500-watt Leland generator was normally used to energize this modified Funk seine. The 350-watt Onan generator was inadequate.

Paddle-Type Electrodes

Paddle-type electrodes (figure 3) were used in the stream sections where it was impractical to use either of the other two types described. These sections were usually narrow or strewn with numerous emergent boulders. Three paddle-type electrodes were used at one time. Each was carried by a man who also carried a dip net. The center electrode consisted of a triangular wooden frame, about 2 feet on a side, wrapped with 16-gage solid copper wire (Shetter 1947). The wire wrappings were at 1/2-inch intervals. A bamboo handle was attached. The outer two electrodes were simply wire loops, 11 to 14 inches in diameter, attached at the end of a handle. Similar loop electrodes have been used in Canada (Canadian Fish Culturist 1950) and in Michigan (personal communication, Dr. D. S. Shetter,

August 1952). A single length of solid 6-gage copper wire, as well as two strands of flexible 6-gage twisted together, was tried for the loops. One seemed as effective as the other. The center electrode (triangle) was connected to one pole of the generator, and the outer two electrodes (loops) to the other. The generator was usually carried in a boat.

This electrode arrangement proved very satisfactory. Three electrodes permitted greater coverage of the stream width than the conventional two. The loops were much easier to handle in the water than the heavier, bulkier triangle. It is possible that a third loop could be substituted for the triangle without loss of shocking efficiency. The usual crew consisted of two men to collect fish and the three carrying electrodes. Fewer men were needed in narrower streams.

Efficiencies

Each sample section on Lost River consisted of a pool and the adjacent downstream riffle. A mark-and-recovery system was used for making estimates of the fish population. Each end of a pool or riffle to be censused was blocked with a 1/4- or 5/8-inch square mesh seine. On the first day, fish were collected and marked and notes were made of the number of each species in each size group. (Size groups coincided as far as possible with groups in length-frequency distribution.) When water conditions permitted, blocking nets were left in overnight and the fish were released on the first day as soon as they had been marked by fin clipping. On the second day, the section was again shocked. Weights and measurements of fish and the number of marked and unmarked taken were recorded. Efficiency was based on the percentage of marked fish recaptured and was used to estimate the total number and weight of fish present. When it was feared that the blocking nets might not stand overnight, the fish were marked and held in live boxes. The nets were reinstalled the next morning if they were down, and the fish released an hour or so before shocking commenced.

It was assumed that the marked fish redistributed themselves among the unmarked fish. This assumption was based on the observation that on the recapture day the proportion of marked to unmarked fish in each category remained about the same for each shocking trip through the section. Schuck (1948) and Cooper (1952) pointed out the possible errors involved in estimating fish populations by mark-and-recovery and the assumptions that must be made.

The data from two Lost River pools are presented in table 1 as examples of efficiencies obtained with the equipment described. Only species comprising a significant weight are shown. Names of fishes are those adopted by the American Fisheries Society (1948). Pool H was shocked for the most part with the two parallel bare wires. About equal effort was expended in collecting fish on both marking day and recapturing day. On each day, two trips--trip as used in this paper is a one-way run through a section--were made through the pool with the parallel-wire electrodes and one trip was made along each edge with the paddle-type electrodes. In pool F the modified Funk electric seine was the only shocking apparatus used. One trip through the pool was made on the marking day and two trips on the recovery day. The physical characteristics of the two pools are given in table 2.

The data show that over-all efficiency in recovering marked fish was good. Recoveries of 50 percent or better were recorded for 18 of 29 categories in which fish were marked. Only 2 categories showed efficiencies of less than 25 percent.

Certain species were more easily captured than others. For example, as a rule, efficiency in recapturing yellowbelly sunfish was lower than that for rock bass, and the efficiency for Centrarchids was lower than that for suckers. Also, large fish were generally more easily collected than small fish of the same species.

DIRECT CURRENT

A 2,500-watt, 230-volt D. C. Homelite generator (as described by Rayner, 1949)

TABLE 1.--Number of fish marked and recovered in two Lost River pools

Species	Size group (Total length, inches)	Pool H				Pool F			
		1st Day	2d Day			1st Day	2d Day		
		Number of fish marked	Number (marked) recovered	Total collected	Percentage efficiency	Number of fish marked	Number (marked) recovered	Total collected	Percentage efficiency
Smallmouth black bass	9.0 and up	-	-	-	-	15	12	17	80
	4.5 - 8.9	68	38	62	56	57	26	124	46
	4.4 and less	45	15	42	33	33	6	61	18
Rock bass	4.5 and up	43	35	74	81	114	69	121	61
	2.5 - 4.4	19	5	55	26	28	10	85	36
Yellowbelly sunfish	4.5 and up	21	3	22	14	122	46	135	38
	2.5 - 4.4	21	6	26	29	15	4	75	27
Green sunfish	4.5 and up	8	4	11	50	-	-	-	-
	2.5 - 4.4	3	1	1	33	-	-	-	-
Hog sucker	11.0 and up	8	7	9	88	7	7	8	100
	7.0 - 10.9	9	9	12	100	8	7	11	88
	3.0 - 6.9	6	5	5	83	4	4	5	100
White sucker	11.0 and up	34	33	50	97	41	39	41	95
	7.0 - 10.9	-	-	-	-	10	10	14	100
	3.0 - 6.9	2	1	1	50	-	-	-	-
Fallfish	7.0 and up	12	9	11	75	6	5	7	83
	3.5 - 6.9	20	9	13	45	11	6	7	54

TABLE 2.--Physical characteristics of Lost River Pools H and F when shocked

Physical features	Pool H	Pool F
Length	562 feet	883 feet
Average width[1/]	44.8 feet	79.4 feet
Average maximum depth of cross sections[1/]	36 inches	41.8 inches
Maximum depth of pool	67 inches	72 inches (approx.)
Visibility	Water somewhat turbid, bottom not visible in water 4½ feet deep	Good, entire bottom visible from surface
Type bottom	Mostly sand and silt, some rocks	Two thirds of bottom strewn with large boulders; one third, sand and silt

1/Based on 34 measurements for Pool H and 37 measurements for Pool F taken at equal intervals along the stream.

was obtained in November 1952. It arrived too late to be used in the initial population study on Lost River but was used in subsequent work. Both the parallel-wire electrodes and the paddle-type electrodes were used with this unit. With the former, the front wire was used at the positive pole; with the latter, the two outside electrodes (loops) were positive. Experiments are planned in which direct current will be used to energize the modified Funk seine. Rayner (1950) and Myers (1951) describe other types of electrodes that could be used.

The parallel-wire electrodes were used in removing suckers from a study area 2.5 miles long on Mill Creek in Grant County. The average width of this stream was 44.5 feet; maximum depth in pools, 5 to 6 feet; bottom type, predominantly gravel; estimated volume of flow at time of sucker removal (December 1952), 20 cubic feet per second; and maximum water temperature during shocking operations, 47° F.

This apparatus proved very satisfactory. An estimated 90 percent by weight of the white and hog suckers (1,542 pounds total) was removed from the study area in two trips. On the first trip, 1,140 pounds of white and 295 pounds of hog suckers were removed; on the second trip (started 3 days after the first was completed), 73 and 34 pounds. Most fish were "attracted" to the positive wire, which was kept close to the surface. Fish would remain at this wire for 5 to 20 seconds, after which many of the fish would become stunned and settle to the bottom. Owing to this "attracting" phenomenon, direct current was judged to be more efficient than alternating current for collecting fish in quiet water. However, in fast water alternating current seemed better. The direct current did not have sufficient "attracting" power to prevent the fish from washing out of the electrical field. Once out, they would quickly recover, making their capture difficult. On the other hand, fish stunned with alternating current usually remained paralyzed for several minutes, even though washed out of the electrical field, and in clear shallow water were easily netted. The difficulty encountered with direct current in fast water was partially overcome by shocking downstream. As pointed out by Rayner (1949), direct current has the advantage of being easier on the fish than alternating current. Fish under the influence of direct current are limp, whereas fish hit by alternating current are stiff and cramped.

While awaiting delivery of the generator just described, a 120-volt, 2,500-watt direct-current generator was tested on Mill Creek. Both the paddle-type and the parallel-wire electrodes were used; the generator was found to be ineffective for collecting fish. After several tests, the electrodes were connected to the 350-watt alternating-current Onan generator, which in every case stunned numerous fish.

Apparently the voltage output from this direct-current generator was insufficient for electrofishing in Mill Creek.

It is realized that the potentialities of direct current are just being developed. Marine fishery workers have shown that pulsating direct current with certain wave patterns is superior to straight direct current (Houston 1949; Groody, Loukashkin, and Grant, 1952). Determination of the most effective currents for fresh-water species should much improve electric fish-collecting methods for inland waters.

AVOIDING RESPONSE

The tendency of fish to avoid capture after once being in the electric field was noted for both alternating current and direct current. For example, three trips with the direct-current shocker were made through pool X (length, 1,760 feet; average width, 77 feet; maximum depth, 41 inches) of Lost River on February 10, 1953, and one trip was made the next day. Fish captured on each trip were held in live boxes. Blocking nets were maintained at each end of the section from before the first trip till after the last trip. The numbers of fish collected on each trip are shown in table 3.

The data show that a smaller number of fish in most categories was taken on the third trip than on the second, yet more of each category were captured on the trip made the following morning than on the third trip the first day. Legal-size (total length 9 inches or over) smallmouth black bass were an exception. These data are interpreted as showing that fish seek cover after being once exposed to the electric current. Such an avoiding response was observed in all collections in which more than one trip with the shocker was made.

ACKNOWLEDGMENTS

Over-all supervision was given by Mr. E. A. Seaman. Mr. J. W. Marron, now with the New Jersey Department of Conservation and Economic Development, actively participated in the development of the methods described. Technical assistance was given by Mr. G. E. Knoll of the Potomac Light and Power Company. Messrs. C. L. Bott, C. L. Hawse, G. W. Branson, and W. H. Clinedinst assisted with shocking operations.

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TABLE 3.--Avoiding reaction, as shown by numbers of fish collected on successive trips with shocker--Pool X, Lost River

Species	Size group (Total length, inches)	Number of fish taken, 1st day			Number of fish taken, 2d day	Total
		1st trip	2d trip	3d trip	One trip	
Smallmouth black bass	9.0 and up	21	1	2	0	24
	4.5 - 8.9	4	32	12	17	65
	0 - 4.4	7	27	4	35	73
Rock bass	2.5 and up	54	45	9	44	152
Yellowbelly sunfish	Same	4	2	1	1	8
Fallfish	Same	36	11	1	11	59
River chub	Same	5	1	1	4	11
Hog sucker	Same	50	16	3	6	75
White sucker	Same	15	8	0	2	25
Total		196	143	33	120	492

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LINERS FOR SPAWNING KEGS OF CHANNEL CATFISH

Part of the loss in channel catfish propagation occurs when clusters of these eggs are to be moved from the spawning kegs to hatchery troughs for artificial incubation. To reduce this mortality in handling, A. C. Balch, superintendent of the U. S. Fish-Cultural Station at Neosho, Missouri, recommends the use of liners in the kegs.

During the past season each of the wooden spawning kegs (regular nail kegs) used for channel catfish propagation at the Neosho Station had a 14- by 17-inch piece of roll slate roofing tacked lightly to the bottom. When the catfish had spawned, liner and eggs were easily removed from the keg, carried in a tub of water to the hatching trough, and there placed on the bottom, under the paddle operated by a small water wheel. The method saved considerable time, the eggs were not disturbed or broken, and there was no fungus growth developing from broken eggs to destroy part or all of the spawn.

SYNTHETIC BINDING OF TROUT DIETS

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ONE OF THE GREATEST PROBLEMS in research on the nutrition of trout, salmon, and other experimental fishes has been the preparation of properly bound diets that would not disintegrate in water. Wolf (1951) tried materials such as tapioca, Mucilose (psyllium seed), and vegetable gums, but none was satisfactory for binding a synthetic diet; he was forced to utilize a combination of gelatin and cooked potato starch. This resulted in a rather complicated procedure for diet preparation, and the inclusion of gelatin made the diets unsuitable for amino acid studies. Halver also used gelatin as a binding agent for synthetic diets with young salmon but reported excessive leaching when the diet contained 75 percent moisture.[1/] Most workers with production diets have used a combination of beef spleen and salt to produce a rubbery mass that binds very well. However, the many variables introduced with fresh beef spleen make this method unsuitable for many critical studies to determine basic nutritional requirements. Even strictly applied research is handicapped when diets are of unequal physical consistency, as growth responses may be more affected by this factor than by the nutritional make-up of the diets. Lord (1935) has discussed the binding properties of other meat products, but none is suitable for most experimental work.

As used in this paper, the term "bind" refers to any physical phenomenon which results in a matrix capable of holding together the finer particles of the diet. Thus, though neither salt nor spleen alone exerts a binding effect, the combination of the two results in a protein denaturation that produces a rubbery matrix that holds the dry-feed particles in physical union. There is no chemical union of the various diet ingredients.

Progress in the production of pellets offers considerable promise in the field of binding. Most methods at present make use of heat to a degree which will require evaluation, as some dietary constituents may be adversely affected. Other problems with pellets include the preparation of experimental diets in small quantities and the inclusion of fresh meats.

An ideal binding agent would have high binding power at low levels, would be physiologically inert, conducive to easy diet preparation, and of reasonable cost. A cellulose product manufactured by the Hercules Powder Company appears to meet these requirements. This product, carboxymethylcellulose, is known by the trade name of CMC. The industrial applications are discussed by Waldeck and Smith (1952). It is a white powder, soluble or dispersable in water. In pure form it is odorless and tasteless. Toxicological tests have shown it to be physiologically inert. Present cost is approximately 70 cents a pound.

A series of feeding trials with CMC as a binding agent for trout diets was made at the Leetown Experimental Fisheries Station. The tests were of a preliminary

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1/ Halver, J. E. A vitamin-test diet for chinook salmon; the water-soluble vitamin requirements of chinook salmon. Univ. of Washington, Ph.D. thesis, 82 pp. 1953.

nature, and it is hoped that other investigators with more adequate facilities for nutrition research will be able to continue the work.

In addition to a binding agent, the preparation of properly bound diets requires a method for measuring the degree of bind. A device for this purpose was developed to facilitate the investigation of CMC. The properties of CMC suggested several algin products which might be equally useful. The binding properties of Irish moss, Kelgin, and Kelcoloid were determined by the measuring device only.

METHODS

In the formulation of the test diets, the primary objective was to compare the binding power of CMC (Type 70-D High Viscosity) with that of fresh beef spleen. However, dry-feed diets bound with spleen received additional nutritional value that was not present when CMC was used as a binder. To evaluate this source of variation, six diets were formulated as listed in table 1.

Diets 1 and 2 were designed to measure any toxic or other physiological properties that CMC might possess for trout. Diet 1, with spleen as the binding agent, was considered the control diet. Diets 3 and 4 were supplemented with small amounts of liver, as it appeared likely that diet 5 (in which CMC replaced spleen in a completely dry-feed diet) would be inadequate to sustain trout. The amount of liver was limited to 10 percent to reduce binding action. It was desirable, however, to test CMC in a completely dry-feed diet that was more likely to be adequate for trout than diet 5. Diet 6, therefore, was liberally supplemented with a variety of protein and vitamin-rich materials. To each diet in which spleen and/or liver was omitted, an equivalent amount of dry material was added in the form of fish meal.

The binding power of any material seems closely related to the total moisture content of the diet. For the first 6 weeks of this experiment, the diets were formulated so that all had the same moisture content (55 percent). This resulted in a great variation in the degree of bind in the diets. This, of course, is what the experiment was designed to measure. However, the diets containing CMC were so well bound that it appeared that poor intake might be creating ambiguous results. To check this possibility, the moisture content of the diets was changed on the seventh week to equalize the degree of bind.

The degree of bind was measured by utilizing a cooky press on which the design plate had been replaced with a small glass funnel. With the cooky press secured vertically on a ringstand, compression of the diet resulted in a long worm that hung freely below the press. When the weight of the worm exceeded the tensil strength of the diet, the worm broke. The weight, in grams, of 10 such worms was taken as a numerical representation of the degree of bind. The average of 5 determinations (50 worms) was taken for each value. The measuring process was started 15 minutes after diet preparation was completed. The degree of bind of each diet was measured at 3 moisture levels selected arbitrarily to bracket the desired range of values and was plotted graphically (see figure 1). From this graph, the correct moisture content was determined for each diet so that all (except diet 3, which was not bound) would have the same degree of bind as the control diet at 55 percent moisture. The moisture content of all diets was calculated by assuming that the fresh-meat portion was 75 percent water and the dry-feed portion, 10 percent water (Tunison 1940). These, of course, are approximate values, and the degrees of bind thus determined are also approximate.

The diets were fed for 18 weeks. The water temperature was 54° F. Fall-spawned rainbow trout averaging 0.62 gram in weight were selected for the experiment. For a 2-week period before the feeding trials began, all fish were conditioned to a diet of 50 percent dry feed and 50 percent meat. The starting weight of each lot was 500 grams. The fish were weighed every 2 weeks and reduced in number so that all lots started the next 2-week period with the same weight. As

TABLE 1.--Diet composition in parts by weight[1] and percentage of moisture in each diet

Diet number	Spleen	Liver	Dry feed[2]	Supplemented dry feed[3]	Fish meal	CMC	Percentage moisture[4] 1st 6 weeks	Percentage moisture[4] 7th to 18th week
1	40	10	50	-	-	-	55	55.00
2	40	10	50	-	-	2	55	66.50
3	-	10	50	-	11.1	-	55	55.00
4	-	10	50	-	11.1	2	55	65.75
5	-	-	50	-	13.9	2	55	65.00
6	-	-	-	64	-	2	55	62.50

[1]To each diet in which spleen and/or liver is omitted, an equivalent amount of dry material is added in the form of fish meal.

[2]Dry feed: fish meal, 45; cottonseed meal, 21; wheat middlings, 20; yeast (Standard Brands, Type 50-B), 10; salt, 4.

[3]Supplemented dry feed: fish meal, 30; Blatchford's Calf Pab (supplemented dried milk), 15; yeast (Standard Brands, Type 50-B), 10; wheat middlings, 10; cottonseed meal, 10; yellow cornmeal, 7; distiller's solubles, 10; wheat-germ oil, 2; cod-liver oil, 2; salt, 4.

[4]Water added to give desired percentage of moisture.

the fish became larger, the total weight of the lots was allowed to increase to 1,000 grams, at which point the weight was maintained after the 10th week.

The amount of food fed was determined by tables of Deuel, Haskell, and Tunison (1942). For the first 6 weeks all diets had equal moisture contents (and equal dry-material contents) and were fed in equal amounts. Starting with the seventh week, water was added to some of the diets to change the degree of bind (table 1). If feeding had continued on an equal basis, the lots on diets with higher moisture contents would actually have been receiving less food. Therefore, all diets were fed on an equivalent dry basis from that point on. The fish were fed three times daily.

The diets were prepared three times a week and kept under refrigeration. Each diet was fed in duplicate. The troughs had separate water supplies, which eliminated any contamination between troughs. The CMC powder was mixed with the dry-feed portion of the diet. No precautions were necessary in adding water, as lumping did not occur. The diets were simply mixed thoroughly by hand and were ready for immediate use.

At the end of the 11th week, hemoglobin determinations were made as an index of anemia. The Sheard-Sanford photometric method (Levinson and MacFate 1946) was utilized. Five analyses were made from each lot.

The experiment was planned statistically as a completely randomized design. Where differences are said to exist, these are orthogonal comparisons which have been tested by analysis of variance.

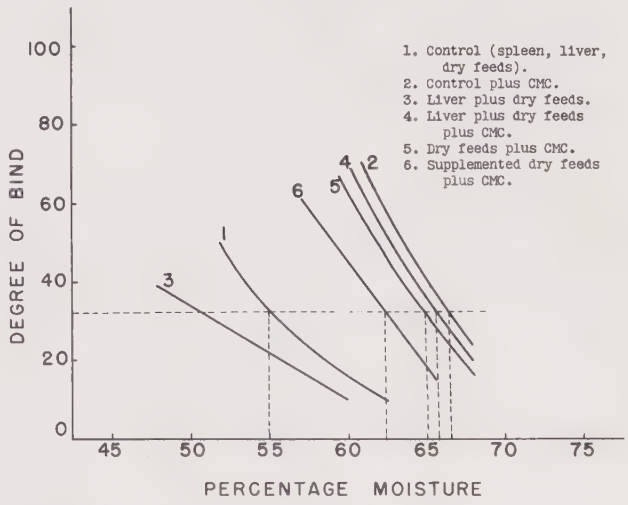

FIGURE 1.--Determination of approximate moisture content to equalize degree of bind (weight, in grams, of 10 worms).

RESULTS

Biweekly percentage of gain is presented graphically in figure 2. After the eighth week, mortality (apparently caused by dietary deficiency) altered the values for diets 3, 4, and 5; and the data have been omitted for these diets at that point. The data for average size (growth), biweekly percentage of mortality, and hemoglobin levels are summarized in table 2.

Table 2 shows no difference between diets 1 and 2 in growth, mortality, or hemoglobin levels. The difference in growth between diets 3 and 4 is highly significant, but there is no difference in mortality or hemoglobin levels. The difference in growth, mortality, and hemoglobin levels is significant between diets 5 and 6. The removal of spleen from the diet (1 + 2 vs. 3 + 4) caused a significant difference in growth, mortality, and hemoglobin levels. There was also a significant difference between diets with meat and those without meat (1 + 2 + 3 + 4 vs. 5 + 6) by all three criteria.

The mortality rate was so high on diet 5 that these lots were discontinued after the 14th week.

The comparative binding power of spleen, CMC, Irish moss, Kelcoloid, and Kelgin is plotted in figure 3. CMC is superior to all other materials, but the algin products at a level of 2 percent are superior to spleen at a level of 40 percent.

DISCUSSION

The results with diets 1 and 2 indicate that CMC is physiologically inert when fed at the level of 2 percent to rainbow trout of this size. There is no depression or acceleration of growth rate or change in hemoglobin levels which can be attributed to CMC per se. However, the binding effect of CMC may radically affect rate of growth. This is most clearly shown in figure 2. For the first 6 weeks, the percentage of gain of fish on diet 2 was suppressed. By adding water to the diet, the growth rate was markedly improved. If a diet is poorly bound, a portion of it may be lost in solution. It appears that a diet may also be bound too firmly, particularly if fed to small fish.

The data presented in figure 1 show that CMC can be used to achieve any degree of bind that is desired. The binding power of CMC far exceeds that of fresh beef spleen and salt. The results with diets 3 and 4 offer an additional biological confirmation of the binding ability of CMC. As fish on both diets developed anemia and suffered a rather severe mortality, it appears that 10 percent fresh beef liver and 5 percent brewer's yeast were not sufficient to supplement these diets adequately. However, the diet bound with CMC (diet 4) resulted in much better growth than the same diet without CMC (diet 3). This would indicate that the fish on CMC-bound diets were receiving more of the total diet. It would appear that the increased growth rate of diet 4 should have aggravated the deficiency condition. Since this did not occur--there was no difference in anemia and mortality between diets 3 and 4--it appears that the intake of vitamins and growth factors from the liver and yeast, as well as the intake of total diet, was improved.

The marked differences obtained with diets 5 and 6 give considerable promise that meatless diets can be prepared for production purposes. The multiple supplementation of the diet 6, however, is not subject to evaluation in the present experiment.

Diets that contained meat were far superior to meatless diets in spite of the degree of supplementation of the meatless diets, as has been shown by many other workers. Of additional interest is the apparent value of fresh beef spleen as compared with an equivalent amount of fish meal. The beef spleen, added to diets containing both liver and yeast, was also effective in preventing anemia and mortality.

The method used for measuring degree of bind is crude but of sufficient accuracy for most purposes. Several other methods were suggested, including the preparation of a standardized pellet that would be subjected to a measured amount of shaking in water, the resulting disintegration to be

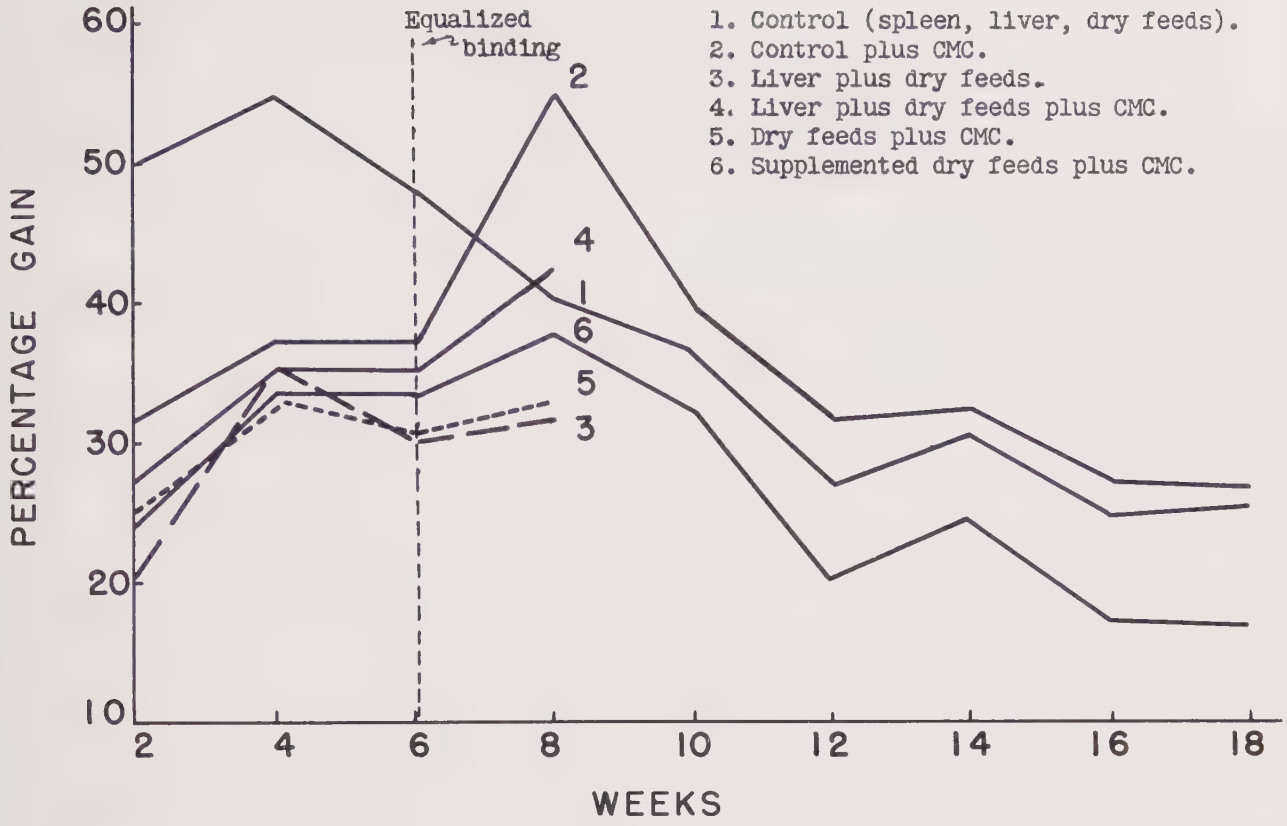

FIGURE 2.--Biweekly percentage of gain.

TABLE 2.--Growth, mortality, and hemoglobin data

Diet No.	Average weight (grams) 14th week	18th week	Average biweekly percentage mortality	Hemoglobin grams per 100 cc.
1-a	7.4	12.0	1.3	11.6
-b	6.7	10.7	1.2	12.0
2-a	6.9	11.2	1.2	12.0
-b	6.0	9.1	1.4	9.4
3-a	3.3	4.7	15.8	7.2
-b	3.4	5.6	16.3	5.2
4-a	5.4	8.1	9.9	6.4
-b	5.2	8.4	11.8	7.0
5-a	3.2	-	16.0	5.6
-b	2.7	-	21.9	3.4
6-a	4.3	6.8	2.2	9.4
-b	4.0	6.2	1.3	9.4

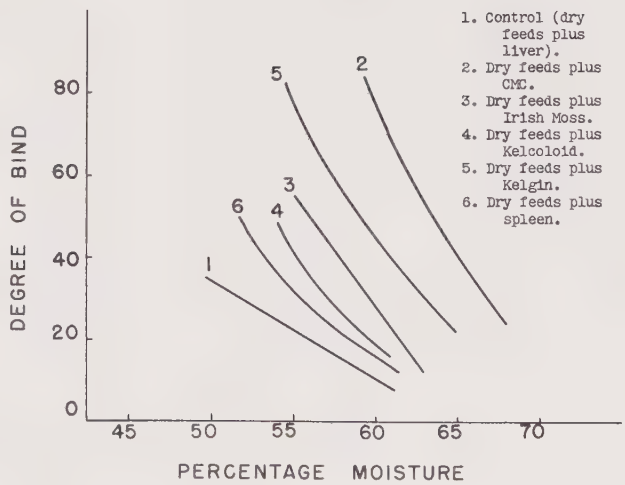

FIGURE 3.--Binding power of CMC, Irish moss, Kelgin, and Kelcoloid at 2 percent; and of spleen at 40 percent. Degree of bind is the weight, in grams, of 10 worms.

measured by turbimetric methods. Unquestionably, more critical methods could be developed. The utility of the cooky press, its availability, and economy are the outstanding advantages of the method used.

It is felt that additional work will emphasize the importance of measuring degree of bind. Many workers have utilized 100 percent beef liver as a control diet in evaluating test diets. Such procedures appear questionable if no measurements are available on the degree of bind of the control diet in comparison to the test diets. The measurement of intake has always been the anathema of fish nutrition research. Equalized binding does not insure equalized intake (palatability may be a major factor), but control of this important variable appears highly desirable.

Future work should determine the effect of dehydration during refrigeration. Casual observations in the present experiment indicated that the degree of bind was altered after 24 hours of storage.

SUMMARY

1. Carboxymethylcellulose, CMC, appears far superior to fresh beef spleen and salt as a binding agent for experimental trout diets. It allows easy diet preparation and is economical, physiologically inert, and effective at very low levels.

2. A method for measuring the degree of bind of a diet and for equalizing the degree of bind between experimental diets is described.

3. Three algin products have been tested for binding action. These materials are less efficient than CMC and are not physiologically inert, but they are more efficient than fresh beef spleen and salt.

ACKNOWLEDGMENTS

Mr. C. E. Dunbar did the hemoglobin determinations. Miss Anne Christine Dunbar assisted in the care of the experimental fish.

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BACK ISSUES

The Editors of THE PROGRESSIVE FISH-CULTURIST frequently are asked for back issues, some of which have been out of print for years. If you would like to help complete some other reader's file of the periodical, send your surplus copies to the Editors.

THE USE OF DYES FOR MARKING FISH

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THE MARKING OF FISH is a highly useful tool in the hands of fishery biologists. It has been used extensively for a long time in different countries for many purposes, such as estimation of the amount of harvestable fish in a body of water, population studies, studies on the rate of growth and movement of fish, and observation of spawning migrations.

Three methods of marking fish have been practiced by hobbyists and fishery biologists. The first method was by tagging, i.e., attaching something to the body of the fish (Rounsefell and Kask 1945). For this method many types of tags--the Peterson tag, jaw tag, nylon tag, and others--have been developed and used in different positions on the fish. The second method was by mutilation such as finclipping (Shetter 1952). Recently a third method of marking fish by use of dyes has been developed (Kask 1936). Experiments on the injection of various dyes into the bluegill (Lepomis macrochirus Raf.) will be discussed in this paper.

All the currently used methods of tagging or marking live fish have one or more of the following disadvantages: (1) The tag may be lost from the fish, the mutilation mark may be obscured by later growth, or dyes and tatoos may disappear; (2) the marking may be inconspicuous and thus be overlooked by the observers, as with clipped fins or faded dye; (3) the tag is not practical to use on fish below certain size limits; (4) the handling procedure inherent in the tagging method may injure the fish so as to cause aberrant behavior or may be accompanied by a high rate of mortality; and (5) the marking method may require elaborate equipment unwieldy for use in the field, as in tatooing.

No marking method circumvents all of these difficulties. However, in the hope that the use of some dyes might provide the solution to some of these problems, experiments were conducted to develop an effective marking procedure with dye.

MATERIALS AND METHODS

Experiments were conducted in aquaria and in a pond of the Farm Pond Laboratory of Alabama Polytechnic Institute. Aquaria that measured 9.5 by 24 by 14 inches were cleaned thoroughly with a detergent and water, placed in the laboratory, and then filled with tap water. The aquaria were supplied with an aeration system using compressed air, and the water was aerated for 3 days prior to the introduction of the fish. A pond that had an area of 1/130 acre and a depth of approximately 2 feet was filled with water 2 days prior to being stocked with fish.

Bluegills, 2 to 4 inches in length, were obtained for use as the experimental fish. From 12 to 15 fish were placed in each aquarium. The water in the aquaria was aerated continuously throughout the experiment and was changed every week; in the pond a continuous flow of water was

This work was done during Mr. Al-Hamid's assignment as a fishery trainee at Alabama Polytechnic Institute under the Point Four Program.

maintained to replace seepage. Fish in the aquaria were fed earthworms, but fish in the pond were given no supplemental food during the experiment.

Because only a limited amount of time could be devoted to this study and only a certain number of aquaria were available, the experiments were restricted to the use of 11 dyes. Each of these either had been used by someone else in a marking study or was recognized as a tissue stain.

The dyes were used at a concentration of 1 percent by weight in distilled water. In each aquarium a number of fish were given injections of one dye and several fish, receiving no injection, were kept as controls.

Dyes were injected into the caudal fin, the dorsal fin, and the cheek of the fish by means of a 1-cc. tuberculin syringe and a No. 27 hypodermic needle. It was not always possible to measure the exact amount of the dye injected, as some of it usually leaked back through the small puncture made by the needle. When each fish appeared to have received an amount sufficient to give the mark desired, injection was stopped. The amount injected varied with the size of the fish and ranged from 0.1 cc. to 0.2 cc.

The method of injecting dye into the caudal fin was to insert the needle into the peduncle near the base of the caudal fin, push the needle into the region of the bases of the fin rays, and then inject the chemical by pressing on the plunger. Using this method, it was possible to color the fin in any of four ways: (1) a spot at the base of the dorsal lobe, (2) a spot at the base of the ventral lobe, (3) the entire base of the caudal fin, or (4) the entire caudal fin. Injection into the dorsal fin was made by inserting the needle near the base of the dorsal fin and then pushing the needle to the base of the dorsal rays before pressing on the plunger. Such injection of the dye colored a spot or the entire fin. Injection into the cheek was made by inserting the needle into the cheek below the eye and then pushing the needle forward--in order to deep the color away from the eye--before pressing on the plunger of the syringe.

EXPERIMENT IN AQUARIA

Marking Fish With One Dye

Fish were kept in 11 aquaria in the laboratory. In each aquarium one dye was injected into the caudal fins. The number of fish marked with each dye and the length of time each kind of mark lasted are given in table 1. The results with each dye were as follows:

Brilliant Vital Red. --The marks were clearly visible in all fish until they died. Marked fish started dying 40 days after the injection, but the unmarked fish began dying earlier. It was apparent from the mortality of both marked and unmarked fish that the deaths of the fish were not caused by the chemical but by some unknown condition in the aquarium. Some of the mortality may have been caused by failure of fish to eat in the aquarium. Some deaths occurred when aeration was stopped because of extended power failure resulting from a tornado.

Alizarin Red S. --Visibility of these marks was very similar to that of brilliant vital red and lasted for the same period. Mortality began on the ninth day, when some fish became heavily infested with the protozoan parasite, Ichthyophthirus sp.

Congo Red. --Visibility of the marks was similar to that of brilliant vital red and of alizarin red and lasted for the same period, 90 days. Some of these fish were heavily infested with Ichthyophthirus sp.

Chlorazol Fast Pink B. --In two fish the dye injected spread all over the body; in the other fish the dye remained in the caudal fin. The mark was clearly visible, with only slight decrease in density of color, in the single fish alive at the termination of the experiment. Mortality was caused by the same factors mentioned for brilliant vital red.

Nigrosine. --Eight bluegills originally received the injections. The marks were clearly visible on the 15th day, at which time both marked and unmarked fish died suddenly. In a repetition of the experiment, 10 fish were marked with this dye. These marks remained visible for 70 days, after which the fish were discarded.

TABLE 1.--Survival of fish marked with different dyes during a 90-day experiment

Dye	Date of injection	Number of fish		Number of fish alive						Average survival (percent)
				30 days		60 days		90 days		
		M[1]	UN[2]	M	UN	M	UN	M	UN	
Brilliant Vital Red	3-20-53	8	5	8	2	2	0	1	0	66.4
Congo Red	3-20-53	7	4	4	2	2	2	2	2	48.4
Alizarin Red S	3-20-53	8	5	4	5	2	3	2	2	47.6
Chlorazol Fast Pink B	3-20-53	9	5	5	4	1	2	1	0	36.8
Trypan Blue	3-21-53	9	5	6	5	0	[3]0	-	-	33.2
Nigrosine	4-11-53	10	5	9	4	5	2	2	0	48.9
Fast Green B	4-11-53	10	5	8	4	7	3	6	2	60.0
Indigo Carmine	3-20-53	9	4	[4]9	4	-	-	-	-	5.4
Trypan Red	4- 4-53	9	4	[5]0	4	-	-	-	-	13.7
Safranin O	3-30-53	9	4	[5]0	3	-	-	-	-	7.6
Gentian Violet	3-21-53	10	4	[5]0	4	-	-	-	-	6.3

[1] Marked fish. [2] Unmarked fish. [3] All fish died from unknown causes.
[4] Color disappeared. [5] All fish died from the effect of dyes within 3 weeks.

Trypan Blue.--The marks were clearly visible for 36 days, after which all fish, both marked and unmarked, died suddenly from unknown causes. The test was not repeated.

Fast Green B.--The marks were clearly visible for 50 days, after which their density began to decrease. Seventy days after the injections some marks had faded and some were still visible, though not clearly. Six of the 10 marked fish were recovered after 70 days and were in good condition.

Indigo Carmine.--The fish lived well, but the color disappeared after 5 days.

Trypan Red.--The response of the fish indicated that this chemical was a strong irritant.. After 3 days color spread all over the body and the fish started dying. All fish were dead after 22 days. Smaller concentrations were not tried.

Safranin O.--These marks were very conspicuous, but the caudal fins started to disintegrate after 4 days. All fish were dead by the end of 15 days. Smaller concentrations were not tried.

Gentian Violet.--The color spread on the rear part of the body. Inflammation of the peduncle was observed after 2 days, and all fish were dead by the end of 10 days. A smaller concentration (0.5 percent) gave the same reaction, and fish died.

Marking Fish With Two and Three Dyes

Of the 11 dyes used in the first experiment, 7 showed promise for marking fish. Combinations of 2 and 3 dyes on one fish were tried in an effort to determine the possibility of using these dyes in identifying many fish. Combinations of Congo red plus nigrosine, Congo red plus fast green, alizarin red plus fast green, nigrosine plus brilliant vital red, fast green plus brilliant vital red, fast green plus trypan blue, and fast green plus alizarin red plus nigrosine were injected into the caudal fin, the cheek, and the dorsal fin. The results of the experiment have been recorded in table 2. The fish were alive and in good condition after being marked with these combinations. All marks, with the exception of fast green, were visible throughout the 45-day experiment. The behavior of the fish indicated that these dyes did not affect the fish. However, the fast green marks started to fade in some

TABLE 2.--Survival of fish marked with combinations of two and three dyes during a 45-day experiment

Dye combination	Position						Number of fish		Percentage survived
	Caudal			Cheek		Dorsal fin	Marked	Survived	
	Entire	Dorsal lobe	Ventral lobe	Right	Left				
Congo Red	-	-	x	-	-	-	3	2	66.7
Nigrosine	-	x	-	-	-	-			
Congo Red	-	-	x	-	-	-	3	3	100.0
Fast Green[1/]	-	x	-	-	-	-			
Alizarin Red	x	-	-	-	-	-	3	2	66.7
Fast Green[1/]	-	-	-	-	x	-			
Nigrosine	-	-	-	x	-	-	3	3	100.0
Fast Green[1/]	-	-	-	-	x	-			
Nigrosine	-	-	-	-	x	-	3	3	100.0
Brilliant Vital Red	x	-	-	-	-	-			
Fast Green[1/]	-	x	-	-	-	-	3	3	100.0
Brilliant Vital Red	-	-	x	-	-	-			
Fast Green[1/]	x	x	x	-	-	x	8	7	87.5
Trypan Blue	x	-	-	-	-	-			
Fast Green[1/]	-	x	-	-	-	-			
Alizarin Red	-	-	x	-	-	-	6	4	66.7
Nigrosine	-	-	-	-	x	-			

[1/] In some fish, fast green marks started to fade after 3 weeks; in other fish, the marks were still visible at the end of the experiment.

fish 3 weeks after the injections, whereas in other fish these marks remained visible until the end of the experiment.

EXPERIMENT IN A POND

This experiment was conducted for the purpose of determining whether the dyes which were promising in aquaria would work as well in a pond. The pond was stocked on May 11, 1953, with 119 bluegills, of which 53 were marked with dyes. The following dyes were used separately: Trypan blue, fast green, brilliant vital red, and nigrosine. Also used were the combinations, Congo red plus fast green and alizarin red plus nigrosine. The pond was drained on June 17, 1953, and the results were noted. The dyes used, the number of fish marked with each dye, and the number of fish that survived are presented in table 3. All marks were satisfactory except those that were made with fast green. Only 2 out of 18 marks made with fast green remained visible.

CONCLUSIONS

Brilliant vital red, Congo red, alizarin red S, chlorazol fast pink B, nigrosine, and trypan blue were nonlethal during the periods of the various tests. All marks made with these dyes were plainly visible at the last observation of each fish. These dyes were successful when used alone or in combination on individual fish. Fast green was also nonlethal, but marks faded after about a month. Trypan red, safranin O, and gentian violet were lethal at the concentration of 1 percent and dosages of

0.1 cc. to 0.2 cc. The lethal effect was the same with 0.5 percent of gentian violet. Indigo carmine was nonlethal, but the color failed to remain visible in the tissues as long as 5 days.

Alizarin red S, brilliant vital red, Congo red, trypan blue, chlorazol fast pink B, and nigrosine showed promise for use in marking fish. The tendency of fast green marks to fade suggests that this dye should not be used without further experimentation.

The successful dyes were used in the caudal and dorsal fins and in the cheek. The marks in the caudal fin were more conspicuous than those in the dorsal fin and the cheek, also more easily recognizable when the fish swam in the aquaria or in the pond. When these marks are used, handling is unnecessary.

The results obtained from marking fish in aquaria and in a pond indicate that this technique can be applied as a management tool to the study of fish populations in ponds, streams, and lakes. It should be especially valuable in marking fish that are too small to carry a tag without bad effects.

TABLE 3.--Percentage recovery of marked fish in a pond after a 36-day period

Dye	Number of fish		Percentage recovered
	Marked	Recovered	
Trypan Blue	10	7	70.0
Nigrosine	10	8	80.0
Fast Green B	10	0	1/ .0
Brilliant Vital Red S	10	10	2/ 100.0
Nigrosine + Alizarine Red	5	5	100.0
Fast Green + Congo Red	8	3	2/ 37.5
Total	53	33	62.3
Unmarked	66	3/ 73	

1/ It is possible that green marks faded.

2/ 11 fish with red marks were recovered. Fast green apparently disappeared from some fish during the experiment; therefore, survival of fish marked with brilliant vital red, or with fast green + Congo red, is unknown.

3/ The increase in the number of unmarked fish was apparently due either to the fish whose green marks faded or to the entrance of some fish into the pond by means of the water supply.

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KORDITE AND MUSKRATS

For several years the Iowa Cooperative Fisheries Research Unit has found Kordite or other plastic-covered wire clothesline very satisfactory for a number of uses, including the attachment of buoys to traps and nets. Unfortunately, it appears that certain elements in this type of cordage are attractive also to muskrats in the area, as Dr. Kenneth D. Carlander writes:

"Muskrats apparently mistake it for some type of succulent root or stalk and cut it off, usually about at water level. For this reason we have had to return to more conventional cordage in waters where muskrats are abundant. Muskrats occasionally cut any of the lines--but never, in our experience, so much as they do the Kordite."

STREAM SEDIMENT REMOVAL BY CONTROLLED RESERVOIR RELEASES

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GRANBY DAM, a feature of the U. S. Bureau of Reclamation's Colorado-Big Thompson project, is located on the Colorado River about 6 miles northeast of Granby, Colorado. The Colorado-Big Thompson project provides for diversion of water from the Colorado River watershed into the South Platte River watershed. Granby Dam acts to regulate and store the runoff of the Colorado River above the site and, under full operation of the project, will also store water diverted from downstream tributaries.

Prior to closure of Granby Dam in September 1949, and to a smaller degree thereafter, a large quantity of sediment was introduced into the Colorado River. This resulted from construction activity both above and below the dam site. Flows between September 1949 and April 1952 were not of sufficient volume to dislodge and carry away the sediment deposited in the streambed.

Stream-bottom samples were taken in 1949, 1950, and 1951. These revealed that a marked change in species of insects present occurred as a result of the deposition and accumulation of sediment. Aquatic insects, typical of the clean rubble bottom formerly existing, became much less prevalent; sediment-loving, burrowing organisms increased in number. This represented a distinct loss in trout foods. The caddisfly larvae and nymphs of several species of stoneflies and Mayflies which tended to disappear were to be preferred, because of their greater size and their accessibility, to the tiny midge larvae or "bloodworms" which replaced them.

The U. S. Fish and Wildlife Service's report entitled "Recreational Use and Water Requirements of the Colorado River Fishery below Granby Dam, Colorado, 1951," recognized the possibility that a sediment problem might develop. As a solution, the report recommended that:

> ... Supplemental releases of water, over and above releases required to maintain the basic minimum flow regimen ... shall be made on demand from Granby Dam into the Colorado River immediately below at such rates and times as may be specified by the Colorado Game and Fish Commission and the Fish and Wildlife Service, jointly; provided that, the volume of water required for such demand releases shall not exceed 5,000 acre-feet in any one year.

The accumulation of sediment in the Colorado River below Granby Dam was discussed during a meeting of representatives of the Colorado Game and Fish Commission and the Fish and Wildlife Service on November 9, 1951. It was agreed that removal of the sediment was necessary to preserve the productivity of the stream, and that the possibility of a flushing operation in the spring of 1952 should be discussed with the Bureau of Reclamation.

It was recognized, however, that the principal benefit from a flushing operation conducted in 1952 would accrue to the 4-mile reach extending from Granby Dam downstream to the Willow Creek confluence. Below the latter point, any alleviation of the sediment problem would be temporary, owing to the heavy load of sediment being carried by Willow Creek as a result of construction activity at Willow Creek Dam and elsewhere in the Willow Creek watershed.

On January 8, 1952, the need for flushing this sediment from the Colorado River below Granby Dam was discussed with Regional Director Batson, Bureau of Reclamation. A tentative plan was developed with assistance from representatives of the Bureau of Reclamation, the Geological Survey, and the Colorado Game and Fish Commission. This plan was transmitted to the District Manager, South Platte District, Bureau of Reclamation, on March 7, 1952.

The schedule recommended for releasing water below Granby Dam to carry away the deposited sediment was as follows:

Day		c.f.s.
1st	-----	200
2d	-----	450
3d	-----	150
4th	-----	450
5th	-----	150
6th	-----	450
7th	-----	300
8th	-----	150
9th	-----	100
10th	-----	75

The operation was intended to coincide with the breakup of ice in the river, so that scouring action of the floating ice would aid in dislodging sediment from the rocks.

The plan as recommended was acceptable, with certain provisions. First, it was necessary to limit maximum flows to 365 c. f. s., theoretically the maximum capacity of a Parshall flume immediately below Granby Dam. Second, curtailment or cessation of operations was to take effect in the event of the formation of ice jams which might result in property damage and claims against the Government. Third, the operation would be terminated at such time as it became evident that continuation would fail to accomplish further removal of sediment.

On April 2, 1952, representatives of the Bureau of Reclamation, the Colorado Game and Fish Commission, and the Fish and Wildlife Service met to complete the arrangements for the flushing operation. It was agreed that (a) the operation would begin at 8:00 a.m. on April 15, 1952; (b) the operation would be directed by A. B. Eustis of the Fish and Wildlife Service and E. G. Nielsen of the Bureau of Reclamation; (c) releases from Granby Dam would tentatively follow the schedule just presented here, except that the maximum release would be 365 c. f. s. rather than 450 c.f.s.; (d) the plan of operation would be subject to any modification that Mr. Eustis and Mr. Nielsen might deem advisable.

Persons who were responsible for conducting operations met on April 14, 1952, at the Granby Pumping Plant. Understanding of details was confirmed. A reconnaissance of the Colorado River from Granby Dam to Kremmling was made to investigate possible property damage that might be caused by a combination of increased flows and ice jams.

At 10:15 a.m., April 15, a landslide partially blocking the outlet to Granby Dam was removed by surging 365 c.f.s. through the tunnel for a period of 15 minutes. This resulted in a peak flow of 170 c.f.s. through the Parshall flume below Granby Dam. (See figure 1.) Besides clearing the tunnel outlet, this release dislodged a quantity of sediment and algae from the streambed immediately below the dam. An odor of hydrogen sulphide was noted, probably because of disturbance of partially decomposed organic matter.

The prescribed controlled flow of 20 c.f.s. was restored after the above action. The crest created by the release of 365 c.f.s. quickly flattened out, owing to channel storage. Most of the material dislodged was redeposited above a beaver dam about 0.5 mile downstream. When the increased flow reached a point 2.5 miles downstream 1 hour and 35 minutes later, it was only slightly turbid. The

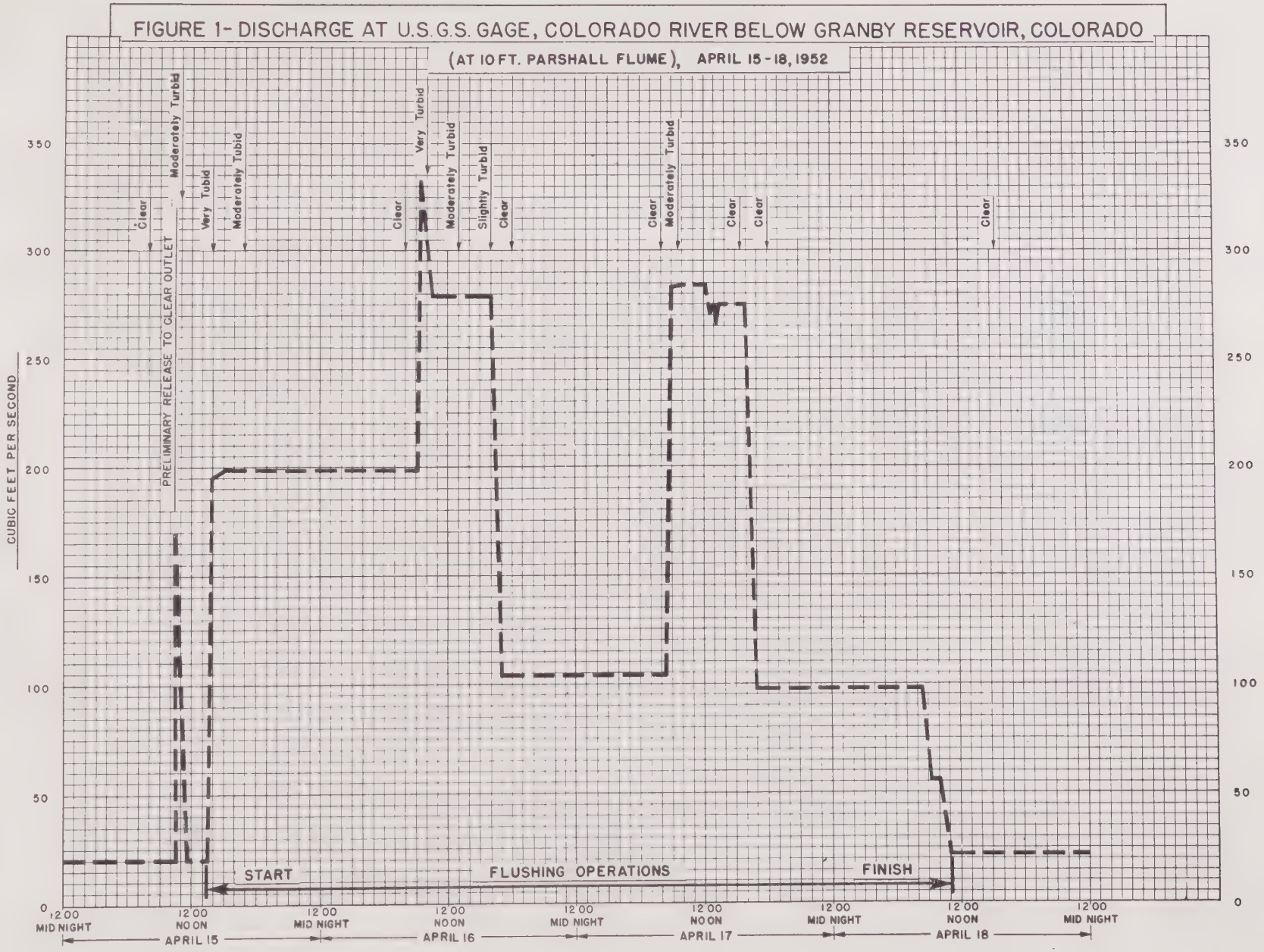


FIGURE 1- DISCHARGE AT U.S.G.S. GAGE, COLORADO RIVER BELOW GRANBY RESERVOIR, COLORADO
(AT 10 FT. PARSHALL FLUME), APRIL 15-18, 1952
CUBIC FEET PER SECOND
350
300
250
200
150
100
50
0
PRELIMINARY RELEASE TO CLEAR OUTLET
Clear
Moderately Turbid
Very Tubid
Moderately Tubid
Very Turbid
Moderately Turbid
Slightly Turbid
Clear
Clear
Moderately Turbid
Clear
Clear
Clear
START
FLUSHING OPERATIONS
FINISH
12 00 MID NIGHT
12 00 NOON
APRIL 15
APRIL 16
APRIL 17
APRIL 18

peak flow at this point did not exceed 60 c.f.s.

It was determined that flushing operations could safely be initiated on April 15. Accordingly, starting at 1:15 p.m., the discharge from Granby Reservoir was maintained at a theoretical rate of 200 c.f.s. (197 c.f.s. at Parshall flume) until 9:05 a.m. the following morning. As the surge to 200 c.f.s. moved downstream, large quantities of sediment and algae were dislodged from the streambed and washed away. The flow of the river at a point 2.5 miles downstream, shortly after the surge reached that point, was approximately 150 c.f.s. and very turbid. By 9:00 a.m. on April 16, however, the water had become quite clear at all points above the Willow Creek confluence.

During the above period it became apparent that the earth dikes which act as wings for the Parshall flume below Granby Dam would be unable to contain a sustained flow of 365 c.f.s., and an effort was made to build up the dikes. It had been planned to increase the discharge from Granby Reservoir to 365 c.f.s. at 9:00 a.m. on April 16; however, it was decided to test the capacity of the dikes by making an initial increase to 325 c.f.s. Theoretically, this was done at 9:05 a.m. The peak flow through the Parshall flume registered 335 c.f.s. about 9:25 a.m. By that time water was flowing over the crest of the dikes in several places: The discharge was reduced by stages until the capacity of the dikes was reached. The theoretical discharge from the dam was then 275 c.f.s., but current meter readings at the flume showed the actual discharge to be 280 c.f.s.

With regard to removal of sediment, the flow of 280 c.f.s. had much the same effect as the release of 200 c.f.s. on the previous day. The initial surge carried large quantities of sediment, and the water flowing past any given point became progressively less turbid.

It was agreed that nocturnal releases from Granby Dam should be well within the capacity of the dikes flanking the Parshall flume, in order to eliminate the possibility of damage to the flume and prevent further erosion of the streambed. In view of the fact that the maximum allowable release was only 280 c.f.s. instead of 365 c.f.s., Mr. Eustis suggested that the maximum flows would be more effective if between-surge flows were 100 c.f.s. rather than 150 c.f.s. as had previously been planned. Accordingly, the discharge from Granby Dam was reduced to 100 c.f.s. at 4:00 p.m. on April 16.

At 8:30 a.m. on April 17 the outlet valves at Granby Dam were set for a theoretical release of 280 c.f.s. This setting produced a flow of 284 c.f.s. at the Parshall flume and caused water to overflow the earth dikes. At 12:30 p.m. the theoretical and actual release was reduced to 276 c.f.s. to prevent further erosion of the dikes.

The surge to 284 c.f.s. on April 17 dislodged a relatively small amount of sediment as compared to the amount dislodged by the surge on April 16; in fact, the water became scarcely more turbid than it had been near the termination of the 280 c.f.s. release on the previous day. By 2:30 p.m. the stream was quite clear at a point approximately 3 miles below Granby Dam and only slightly turbid a short distance above the Willow Creek confluence. It was apparent that little more could be accomplished by continuation of the flushing operation under the prevailing maximum-flow limitation. Mr. Hillen, acting for Mr. Eustis, directed that the rate of release from Granby Reservoir be reduced to 100 c.f.s. at 4:00 p.m., April 17; to 50 c.f.s. at 8:30 a.m., April 18; and to 20 c.f.s. at 10:00 a.m., April 18. Actual flows resulting from this action are shown in figure 1.

Figure 1 presents a graphic record of the flow of the Colorado River during the flushing operation, as recorded at the Parshall flume immediately below Granby Dam. Also included in figure 1 are notations relative to the turbidity of the water at a point approximately 1.5 miles further downstream.

According to Bureau of Reclamation computations (based on streamflow as recorded at the Parshall flume below Granby Dam, rather than theoretical releases),

the total volume of water released from Granby Reservoir on April 15, 16, 17, and 18, 1952, amounted to 993.25 acre-feet. The interim plan for operation of Granby Reservoir calls for release of 20 c.f.s., or 39.67 acre-feet, per day during the month of April; therefore, the volume of water released specifically for the flushing operation amounted to 834.57 acre-feet.

A quantitative test of the sediment deposit in a large pool about 2.5 miles below Granby Dam was made by Fish and Wildlife Service personnel on April 14, 1952, prior to the flushing operation. Twenty-four samples, made with the standard U. S. Geological Survey sediment-sampling device, were taken at 3-foot intervals in direct line across the stream. As soon as the flow of the stream had leveled at 20 c.f.s. after the flushing operation, a second test was conducted at the same location. This test duplicated the first in every respect except that the position of each sample was shifted approximately 6 inches along the control line to eliminate the possibility that the result might be influenced by the previous sampling.

The preoperation test indicated an average sediment depth amounting to 1.39 inches; the average depth after the flushing operation was found to be 0.49 inch. Selection of a pool as the site of the quantitative tests had been motivated by the fact that pools, as compared to riffle areas, afford relatively unfavorable conditions for sediment removal and therefore would experience minimum benefit from the flushing operation. It is considered, therefore, that from a strictly quantitative standpoint the flushing operation was at least 60 percent effective in removing sediment from the portion of the stream channel subject to inundation by a flow of 20 c.f.s.

During the postoperation test it was observed that very little of the sediment remained in the central portion of the pool where the current during the flushing operation had been strongest. In quiet water near the margin of the pool, however, little, if any, decrease in the depth of the sediment deposit was evident. Subsequent reconnaissance revealed the prevalence of comparable conditions throughout the entire 4-mile reach of the Colorado River between Granby Dam and the Willow Creek confluence; most of the sediment had been removed wherever the increase in flow had been sufficient to produce a strong current, but much remained in eddies and backwaters. It was obvious that the flushing flows had attained their maximum efficiency in riffle areas; there, virtually complete removal of sediment had been accomplished. In some places the area of streambed that had been inundated at some time during the flushing operation was well defined by an accumulation of sediment and debris along the margins.

It is considered that the flushing operation achieved a substantial degree of success in restoring habitat conditions that are favorable to organisms which serve as food for trout. The removal of sediment from riffles was of particular significance, as riffle areas are normally the most important segments of a stream with regard to the production of food organisms. An immediate increase in the amount of trout food produced in the Colorado River is not to be expected, however, as time will be required for food organisms to repopulate areas of the streambed from which they had been eliminated. Furthermore, the ultimate success of the flushing operation will depend upon continuous maintenance of the streambed as productive habitat.

Sediment deposited at the edge of the stream channel during the flushing operation constitutes a threat to future production of trout food, as this sediment, if washed into the stream, would cause a recurrence of unfavorable habitat conditions. Fortunately, the greater portion of the sediment lies above the level that would be reached by flows contemplated under the operation of Granby Reservoir. It is hoped that the deposits will be stabilized by compaction and that a vegetative cover will develop.

It is difficult to estimate the extent to which strict adherence to the original plan might have increased the efficiency of the flushing operation. The almost complete absence of ice on the river between Granby

Dam and the Willow Creek confluence precluded scouring of the streambed by floating ice. Releases at the rate of 365 c.f.s. would probably have been more effective in removing sediment from pools and might also have permitted less to settle along the sides of the stream channel. If the various stages of the operation had been of 24-hour duration as originally planned, the peak flows would have had greater opportunity to overcome the effect of channel storage and thus would have attained higher crests. It is recognized, however, that deviation from the original plan was absolutely necessary, and it is believed that the flushing operation attained the maximum efficiency possible under the prevailing circumstances.

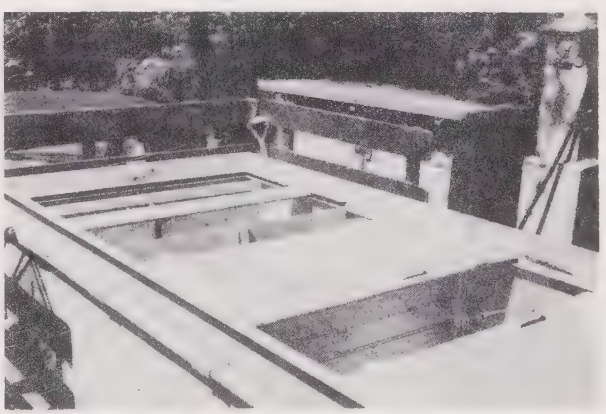
A FISH DISTRIBUTION UNIT

Some features of the fish-distribution unit in use at the State fish hatchery at Montague, Massachusetts, are described by Ralph Bitzer and Alfred Burnham:

The tank is made of 10-gage sheet metal 8 feet 6 inches long, 4 feet wide, and 30 inches high, which allows 6 inches for screenage, water intake to pumps, and four separate sections for fish. Angle iron (1-1/4 inches) is used to case partitions, reinforce ends, and make a shelf for wood covers; angle iron (1-1/2 inches) is used to case the tank top. Two pieces of strap iron (1-1/4 by 1/8 inch) are grooved into partitions and bolted to upright casings to hold the tank rigid. Iron hangers (1/2 inch) are welded to the corners for bolting to the truck; iron runs (3/4 by 1/2 inch) are welded to the tank bottom, starting from the edge and evenly divided. The partitions or shelf extends to within 4 inches of the top; beneath is the water supply inlet with a 45° angle fitting and reducer. A threaded flange welded on the lower middle side allows fastening a wood jacket around the tank if desired. The end covers are locked in by angle iron (1-1/4 inches) and made with ship lap joints. This allows the water level to stay the same regardless of distance or travel conditions. In icy weather the partitions and center cover supports are raised with wood strips (1-1/8 inches) and looser-fitting covers are used. The carrying capacity runs to 1,000 pounds, depending on the weather and the efficiency of the circulating system.

The tank makes use of two Briggs and Stratton air-cooled gasoline motors, which are described as "very satisfactory in performance." Used in combination with the motors are two Homart centrifugal water pumps (1-1/2 inches), recommended by Bitzer and Burnham as being "simplified in construction and easily dismantled for cleaning." These combined units are mounted one behind the other. Valves are available also for independent use when necessary, as during freezing weather.

In order that the driver of a truck on which the distribution tank is mounted may know at all times just how efficiently the apparatus is functioning, the windshield support of the truck carries the dial of a Trusteed Boat Speedometer that has been attached to the main line. This dial will show without delay any alteration in the smooth running of the pumps and motors.



THE EFFECTS OF ANTIBIOTICS AND ARSANILIC ACID ON THE GROWTH OF RAINBOW TROUT FINGERLINGS

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DURING RECENT YEARS numerous growth study reports (Merck and Company 1952) on certain domestic animals have shown that some antibiotics, when administered orally in low concentrations, have remarkable growth-stimulating effects upon poultry and swine. Unsatisfactory results have been obtained with cattle except where the antibiotics have been given by injection, probably because the ruminant stomach of the bovine animals destroys or alters the antibiotic activity.

Antibiotics have been used by some trout-hatchery directors in the past, on a nonexperimental basis, on the supposition that growth stimulation might be effected in the fish as in poultry or swine since various drugs used in these animals can be used in trout with good results.

The following experiment was conducted to determine the effects of a low concentration of several antibiotics and arsanilic acid on trout.[1/] The tests were repeated at the conclusion of the initial experiment with approximately the same results obtained. At the time this work was in progress, no similar work had been reported on fish. When the tests were being repeated, however, it was discovered that similar studies had just been completed by Wolf (1952), whose findings agree in general with those of the present writer.

Wolf's work was concerned with brown trout. Two basal diets were used in his investigations. One diet consisted entirely of vegetable meals with the exception of gelatin, which was used as a binder. The second was similar to the first except that it also contained fish meal and dry skim milk. Wolf's nutritionally poor basal diet was used in order to allow the antibiotic supplements to show their effects upon growth in greater contrast than would be possible with a good diet.

The basal diet in the present work differed from Wolf's in that a nutritionally good diet was used. The reason for this was that hatchery managers using antibiotic supplements were, or would be, using them in their standard nutritionally well-balanced fish feed mix. It was, therefore, desirable to determine antibiotic effects upon growth in rainbow trout under these conditions.

Methods and Materials

Experimental fish used were rainbow trout, Salmo gairdneri Richardson, hatched in experimental troughs in the laboratories at Loma Linda. These troughs measured 1 by 1 by 5 feet long and were covered with a screen lid. Inflowing well water was cooled to about 14° C. with a temprite photographic-type water cooler. The water temperature was then maintained at approximately 12° to 18° C. The water was filtered through charcoal to remove chlorine. No mortalities due to disease occurred at any time during the tests.

Three hundred sixty fish, 1-1/4 to 2 inches in size, were segregated into 6

1/This work was sponsored in part by the California Trout Company, Mentone.

groups of 60 fish each. These groups were weighed in a container with water and placed in individual troughs. All antibiotics were mixed in the feed ration at the rate of 10 milligrams per pound of feed. This was based on figures used in experiments reported in the prevailing literature.

The antibiotics used were:

Aureomycin: Aurofac A (Lederle) contains 1.8 grams of aureomycin per pound of supplement and a level of 0.5 milligram of vitamin B_{12}.

Terramycin: Terracon 180 (Charles Pfizer & Co., Inc.) contains 180 grams of terramycin hydrochloride activity per pound of supplement.

Penicillin: Vitamin B_{12} and antibiotic feed supplement contains 12.5 milligrams of vitamin B_{12} per pound of supplement and 2 grams of procaine penicillin. (Merck & Co., Inc.)

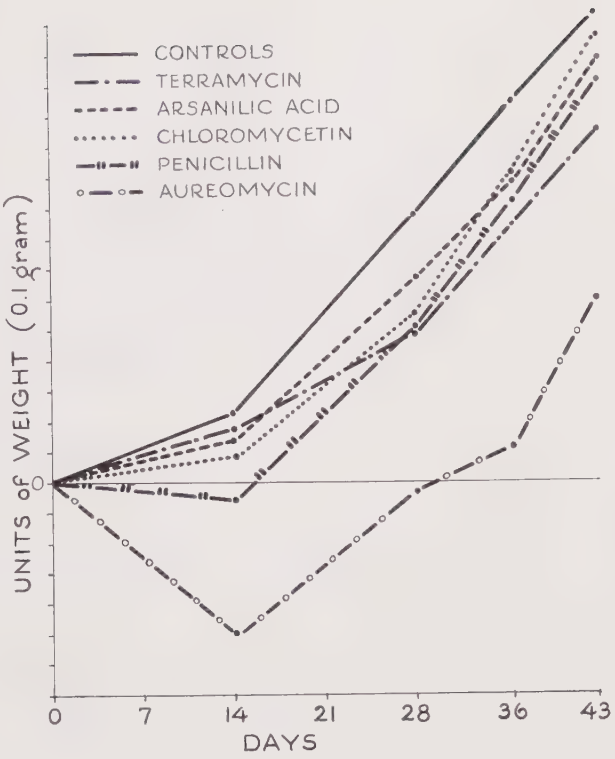
Chloromycetin: Mycelial Meal No. 61341 (Parke, Davis & Co.) contains 1.88 milligrams of chloromycetin per gram and 3.8 micrograms of vitamin B_{12} per gram.

As liver contains more than the normal vitamin B_{12} requirement, it is assumed that the additional amounts of the vitamin in some of the supplements do not alter the growth effect beyond the amount in the basal diet.

In addition to the antibiotics, arsanilic acid was used in the recommended concentration of 0.01 percent or 9.9 milligrams per pound of ration. Ground beef liver was used as the ration for the first half of the test; a 1:1 ratio of beef liver and beef heart was fed during the second half. The fish were fed 3 times a day. At intervals of 14, 28, 36, and 43 days, the individual lots of fish were weighed and the average weight per fish was computed.

Results and Discussion

The accompanying graph shows the rate of gain or loss in weight per fish after



each weighing during 6 weeks. None of the groups fed antibiotics or arsanilic acid showed so rapid an increase in weight as the control group. The fish fed penicillin and aureomycin actually lost weight during the first 2 weeks. Recovery was good in the group fed penicillin but poor for those fed aureomycin. All others were grouped fairly close together in the rate of gain per fish for the duration of the tests.

From these preliminary data it may be concluded that the antibiotics and arsanilic acid tested do not show a growth stimulation in fingerling rainbow trout when they are fed a low concentration in a good basal diet for a period of 6 weeks. Apparently there are significant differences in metabolism between fish and warm-blooded animals such as poultry and swine, and/or the action of the drugs on the microflora--undoubtedly different in these animals--may account for these differences. The evidence indicates instead a slight or marked growth inhibition response in the fish. Whether or not these supplements tested are beneficial or harmful to the fish in other respects, such as resistance to disease, was not determined.

In view of the fact that antibiotics are being used in some trout hatcheries, it appears that further studies, perhaps actual field tests, should be conducted to determine the advisability of continuing this practice. Because thousands or millions of fish are raised annually in some hatcheries, and the market value is based on fish weight, it appears economically unwise to pay for supplements which inhibit a normal increase in growth of fish.

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MALACHITE GREEN USED TO PREVENT FUNGUS ON LAKE TROUT EGGS

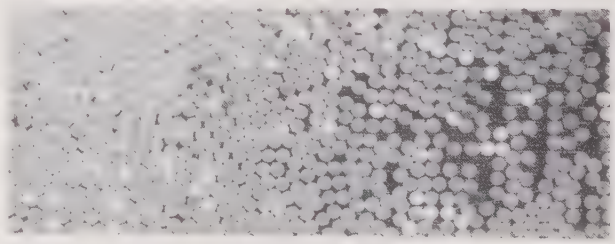
To eliminate the problem of picking dead lake trout eggs, Russell Robertson, superintendent of the State fish hatchery at Marquette, Michigan, recommends the following treatment with malachite green:

A stock solution is made by dissolving 1-1/2 ounces of malachite green (oxalate crystals, zinc free) in 1 gallon of water. A single trough with a flow of 6 gallons of water a minute should get 3 ounces of the stock solution at the head of the trough at 8 a.m. and 5 p.m., daily. Two troughs in series with the same water flow should get 3 ounces of the stock solution at the head of the upper trough and, after approximately 75 percent of this solution has left the upper trough, an additional 1-1/2 ounces of the solution at the head of the lower trough. This treatment also is given twice daily. When silting conditions exist, it may be advisable to use 6 ounces of stock solution for the upper troughs and 3 ounces for the lower troughs twice daily.

"In 1951-52," writes Mr. Robertson, "10 trays of lake trout eggs were treated twice daily, 7 days a week, with malachite green. Dead eggs were not picked off and trays were moved only to remove sediment on the eggs--necessary but once a week.

"Treatments were begun November 8, 1951, and continued daily until January 3, 1952, when eggs were 'rung' up. During this period little or no fungus developed on dead eggs. After the eggs were shocked, dead eggs were picked off. This was the only picking done. To test further the efficiency of malachite green in preventing fungus, dead eggs were placed on 2 egg trays on January 10, 1952. One tray was placed in untreated water as a control; the other was left in the trough with the eyed eggs and was treated morning and night. The untreated eggs showed fungus at the end of 3 weeks, but no fungus had appeared on the treated tray. Heavy silt was present in the troughs, and it had a tendency to adhere more to the dead eggs than to the eyed ones.

"To check further on the toxicity of malachite green, the treatment was increased from 3 to 6 ounces per trough. This treatment was started on February 1, 1952, and was continued through the month with no ill effects on the eyed eggs or on the fry. No further fungus growth was noted on the silt-covered dead eggs. Eggs hatched on February 26, 1952."



(Photo, Dr. Leonard N. Allison, 1/10/52)

A METHOD FOR RECORDING MEASUREMENTS OF CERTAIN MOLLUSCS, ARTHROPODS, AND FISHES

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WHILE CONDUCTING A SURVEY of softshell clam (Mya arenaria) populations in the Sandy Hook Bay region of New Jersey during the summer of 1952, the writer modified a well-known method--a method commonly used to measure fish, by perforating celluloid, aluminum, or other material--to facilitate the measurement of these shellfish. The essential and distinctive feature of this modification was the enclosure of graph paper within a protective jacket of aluminum foil. This use of graph paper served the dual function of recording and measuring, as the graph paper was a "built-in-ruler."

The special merits of this recording-measuring device are:

1. It is more efficient than the commonly used standard vernier caliper yet gives just as reliable measurements.
2. It greatly simplifies the recording of the frequency distribution of the measurements.
3. It is an excellent tool for population studies in which several hundred specimens are measured.
4. It has been successfully used in the morphometry of several species of animals, Mollusca and Arthropoda.
5. The rapidity of the method enables one man to measure upwards of 1,000 "seed" clams (10 to 25 millimeters long) in their natural habitat and then "replant" them, all on the same tide. This is especially desirable in growth studies.

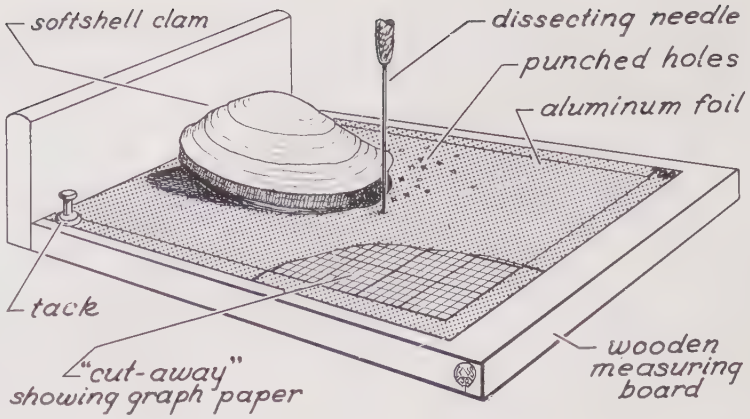
The recording-measuring unit is made by rubber-cementing graph paper (ruled into millimeter units) within an envelope of aluminum foil. An organism to be measured is picked up by the investigator with his left hand and laid upon the measuring board in the desired position (as for a length, height, or width measurement) with one end of the animal abutting the upright end of the board. With a dissecting needle held in his right hand, the investigator then punches a hole through the aluminum jacket at the opposite end of the animal (see figure).

The tabulation of the recordings that are punched into the recording-measuring unit can be made in the laboratory. The upper layer of aluminum foil is peeled off and the punctured graph paper exposed. The punctures occurring on each line of the graph paper are then counted and recorded as linear measurements on frequency charts. To avoid tabulating a measurement twice, it is convenient to ink each puncture as it is counted.

In the studies conducted by the writer, some of the readings were made to the nearest 0.5 millimeter. The error inherent in these readings was $\pm$ 0.25 millimeter. Although the percentage of error depended upon the length of the animal measured, the error was certainly less than 2.5 percent when shellfish more than 10 millimeters in length were measured. But then, this degree of accuracy is not always necessary or even obtainable. Thus, for example, Lunz (1952) has questioned the propriety of using a unit of

measurement less than a millimeter when measuring certain molluscs, such as oysters, with a vernier caliper.

When dealing with measurements--which are always approximations--we should apply the fundamental concepts of computation with approximate data. We should know the meaning of unit of measurement and significant digits and how to round numbers and when and why this is necessary. Yet, if we consult even the most recent biological journals, there is ample evidence that either the knowledge of these concepts is not widespread, or the concepts are not fully understood by most biologists or even by some statisticians. As the topic of computation with approximate data is largely ignored in textbooks of statistics, the reader is encouraged to consult Shuster (1948, 1949) for a comprehensive discussion of this subject.



An illustration of the measurement of a clam by means of the recording-measuring unit.

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CANDLING TO DETECT HEMORRHAGES

The steelhead and salmon fingerlings migrating to the sea are subject to injury and mortality while passing through unscreened hydroelectric turbines, and for several years the Oregon Game Commission has sought to determine the extent of this injury and mortality. Examination for internal injury and hemorrhages has been a particularly time-consuming operation. J. B. Dimick and Cole M. Rivers of the Oregon Game Commission have recently reported, however, that candling with an artificial light is a simple, inexpensive way to detect hemorrhages, regardless of their severity or location.

A three-cell flashlight is used for the candling. An opaque covering, perhaps aluminum foil, is fastened over the lens of the flashlight. In the center of this covering an oval opening, about 2 inches long and 1/2 inch wide, is made. A fish is first placed across the opening in such a position as to obstruct all light and then is moved about over the opening so as to permit light to penetrate all parts of the body. Each side of the fish is carefully examined in this manner.

Use of candling is limited only in that bodies more than 9 to 10 inches in length are not completely penetrated by the light.

TOXAPHENE AS A FISH TOXIN

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IN RECENT YEARS fish kills occurred in many Arizona farm fishponds as a result of aerial dusting of agricultural crops with insecticides. Ponds near fields being dusted or near wind-drifted material had partial or total kills of fish. Young populations usually suffered most severely. Toxaphene, a chlorinated camphene, was the insecticide causing the mortality.

Because of these observations and the reports of fishery workers in other areas, it was decided to study toxaphene as a possible toxin for fish population control. Experiments showed that 1 part in 10 million produced a total kill on carp at 65° F. in 72 hours. Two small lakes in Apache County were selected for field trial with toxaphene at the above concentration.

Lyman Reservoir near St. Johns was first treated with this material in August 1951. Various portions of the lake were treated with an emulsified solution of toxaphene and aromatic liquids, and the remainder was treated with toxaphene dust applied in dust form or emulsified with water and sprayed onto water surface. The dust form was emptied directly into the propeller wash of the outboard motor.

The condition at time of treatment was:

Surface water temperature--70° F.
Water depth maximum-------12 ft.
temperature----69° F.
pH----------8.6
Total dissolved salts---370 p.p.m.
Secchi disc reading----------6 in.
Surface area----------58 acres
Total volume--------385 acre-feet
0.7 pound 40-percent toxaphene applied per acre-foot to achieve 0.1 p.p.m. concentration.

Carp became distressed and began dying within 12 hours. The die-off continued for 48 hours, with a kill of 220 tons of carp (estimated), 3,000 pounds of bonytail (Gila robusta elegans), 29 largemouth black bass, 31 bluegills, 17 brown trout, and several hundred bullhead catfish.

A heavy rain 2 days after the treatment placed an additional 300 acre-feet of water in the lake and almost completely stopped the die-off of fish. Drainage of the entire lake within a few hours after the rain revealed 2,000 large carp, 3,000 bonytail, 112 largemouth black bass averaging 6 pounds in weight, and 192 channel catfish weighing from 3 to 12 pounds each. Not a single channel catfish was noted during the period of toxicity in Lyman Lake. Later use of the material at higher concentrations was very effective on this species.

Lyman Reservoir contains 32,000 acre-feet and covers 1,300 surface acres when full. The total fish population was in excess of 340 pounds of fish per surface acre at lake capacity. Turbidity (secchi disc) was reduced from 6 inches to 4 feet. A plankton bloom has been very prominent during all warm seasons since the control measures were taken.

An experimental plant of 3,600 6-inch rainbow trout was made in June 1952. The next May these trout averaged 16 inches in length. Though the population was very limited in number, the catch was 1.2 fish per hour for the limited number of anglers at this early date. All previous plants of trout in Lyman Reservoir "disappeared," as far as the angling public is concerned.

Beckers Lake near Springerville was treated in October 1951 with 0.1 p.p.m.

toxaphene. This lake (106 surface acres) was heavily infested with carp and yellow perch (Perca flavescens). A white volcanic ash caused a constant "milky" turbidity that reduced secchi disc visibility to 12 inches. All nonemergent vegetation had disappeared within a few years after carp had been introduced about 1916.

The temperature was 52° F. on surface and 51° F. at maximum depth of 29 feet. The pH remained at 8.2 during the operation. Thirty hours after the application of toxaphene, distress was shown by yellow perch, then by golden shiners and a few small carp. Forty-eight hours after the treatment, many thousand 2- to 4-pound carp were circling frantically on the lake surface. Carp died for the next 11 days, after which no fish activity of any kind could be found.

The lake was sampled periodically for 2 years, but not a single rough fish was observed.

Twenty-five thousand rainbow trout fry were planted in the spring of 1952. A sample (121 fish) indicated that these fish grew at an average rate of 1.2 inches per month for the first year. During the winter the lake turbidity dropped from 1 foot to 7 feet. Though record wind velocities have occurred since the treatment, the lake has not appeared "milky."

A chlorinated camphene compound manufactured by the Hercules Powder Company of Wilmington, Delaware, toxaphene is completely insoluble in water, soluble in organic solutes, and has a density of 1.6. Toxaphene may be absorbed through the skin. The estimated fatal dose is 60 mg./kg. body weight, orally. Continued ingestion of small quantities may cause liver damage (Merck Index).

To produce toxic symptoms, a cow would have to drink 18,000 gallons of water per day from a lake treated with 0.1 p.p.m. toxaphene. On four occasions, livestock showed no toxic symptoms after being restricted for 60 days to lake water that had been treated with toxaphene at 0.1 p.p.m.

Frogs and water snakes are the only vertebrates other than fish that have exhibited toxic symptoms in treated waters. Insect life is severely affected but not eliminated. Where large numbers of rough fish are allowed to remain in a treated lake, the resulting fertilization produces a rapid increase of zooplankton after dissipation of the toxic material. The appearance of zooplankton is used as an index to determine the dissipation of the toxaphene, and plantings are made as soon thereafter as possible in order to gain such advantage as may be had from the fertilization resulting from dead fish.

Toxaphene breaks down under alkaline conditions. Treated waters with a pH of 8.0 or higher have been replanted with desirable fish within 4 weeks.

On the San Carlos Reservoir of the Gila River, an experimental treatment destroyed 800 tons of an estimated 1,100-ton carp population, 2 million stunted crappie, a large number of yellow bass (Morone interrupta), and a small percentage of the channel catfish. Results indicate that partial population controls may be achieved in large lakes at a cost as low as 5 cents per acre-foot of water treated. Results further bear out the findings of Lawrence (1950), as applied to large reservoirs. The limiting condition is that the distressed fish shall have no opportunity to migrate into a supply of fresh water.

When the same precautions for handling are observed, toxaphene is no more dangerous than other materials regularly used as herbicides. As toxaphene breaks into nontoxic substances at 190° F., there is apparently no danger in human consumption of fish so destroyed.

In summary: water used for domestic purposes should not be treated; streams or lakes with a large inflow would give a very small kill; though a deep lake has not yet been treated, a good kill is unlikely since toxaphene used in dust form falls rapidly to the bottom.

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DIVIDENDS FROM RESEARCH

RESEARCH DOES BRING RESULTS

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Illinois Natural History Survey
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In 1951 the closed spring season and the 10-inch legal limit on largemouth black bass were deleted from the Illinois Fish Code. For 28 years (these restrictions were introduced in 1923) Illinois anglers had observed the Code restrictions and had been patiently waiting for them to produce good bass fishing. Accumulated evidence suggested that bass were less numerous than at the time when the restrictions first appeared.

The decision to eliminate the restrictions on the taking of largemouth black bass was based on a 10-year investigation of the factors controlling largemouth black bass populations, primarily at Ridge Lake, Coles County, Illinois. This lake is an artificial impoundment of 18 acres, opened to controlled public fishing in the summer and constructed with drain outlet so that at 2-year intervals or oftener fish may be censused, marked, and replaced in the impoundment.

Research on the largemouth has shown that closed seasons and length limits are relatively unimportant in largemouth black bass management.

1. In the period 1941-51, more than 10,800 bass were removed from Ridge Lake, all originating from an initial stocking of 435 fish. The bass population was just as large in 1951 as it had been in 1942 and 1943. This indicates that the species responds well to correct management practices.

2. There was no relationship between the number of sexually mature bass in Ridge Lake at spawning time and the number of bass fry produced. In 1941, 11 bass spawners per acre were present in the lake and bass fry numbered 8,400 per acre; in 1948 and 1950, when very few bass fry could be found, the numbers of bass spawners were 77 and 32 per acre, respectively. In other years the numbers of spawners and the numbers of fry produced varied, but there was no correlation between numbers of adults and young.

3. The limiting factor in the success of bass reproduction was the amount of predation on bass eggs and yolk-sac fry by small fishes. In years when the fish population of Ridge Lake was culled of small fishes (largely bluegills) in March prior to the bass spawning season, the average number of bass fry produced was 50,500; in alternate years when small bluegills were present in the lake, the average number of bass fry produced was 875! A population of small bluegills that numbered around 1,800 per acre almost completely curtailed the success of bass reproduction, while a population of 100 or fewer small fish per acre seemed to have little or no influence on the survival of eggs and fry.

4. Survival rates of bass fry up to sizes of 5 to 10 inches ranged from 1 in 29 to 1 in 195, with an average of about 1 in 33. At this average rate of survival, from 10,000 to 25,000 fry would have been sufficient to replace the bass taken by fishermen in any one year at Ridge Lake. From 2 to 5 pairs of bass could produce these numbers of fry if the numbers of small bluegills in the lake were low.

5. Bass readily became "hook wise," and there seemed to be little chance of overexploiting a population of these fish, regardless of the fishing intensity. Bass

populations dwindle over a period of years because of inadequate replacement of adults that are lost through angling and natural mortality. When small bass were taken by anglers, the growth rate of the bass remaining increased, so that young fish reached one-half pound in weight early in the second year of life. The average life span of largemouth black bass in Ridge Lake and elsewhere in Illinois was less than 10 years.

Here then is a species that is highly vulnerable from the egg to the fingerling stages--vulnerable not to human predation, but to predation by small fishes that inhabit the same waters. It therefore becomes faulty reasoning to assume that the curtailment of human exploitation during the spawning season will allow the adequate survival of bass spawn, particularly when it has been shown that under full protection from human interference, no relationship existed between the number of bass spawners and the number of young bass produced.

Research has shown the real causes for the depletion of largemouth black bass populations. As a result, fishermen and lake owners may have a longer fishing season for this species and may direct their individual or collective attention toward activities that will improve their sport.

MIGRATION OF STOCKED LEGAL-SIZE TROUT

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The inclination and ability of stocked legal-size trout to migrate from the spot where they are planted are of greater than academic interest to the fishery manager. The number of such stocked fish which wind up where they belong--in the anglers' creels--may be increased by use of planting procedures that are based upon facts regarding these inclinations and abilities. This is particularly true of plants that are made in streams where movement of the fish may result in their entrance either into areas that are inaccessible to the public (posted private property or physically inaccessible sections such as narrow, precipitous canyons) or into areas where losses of the fish occur (irrigation canals and similar diversions).

The Fisheries Research Section of the Colorado Game and Fish Department conducted, in conjunction with other phases of trout-stream investigations, a 2-year study of the migration exhibited by stocked legal-size trout. The studies were made on the North Fork of the South Platte River, a stream representative of many trout streams in the State. The resulting data are, of course, applicable only to similar waters under similar stocking conditions.

During the 2-year period more than 3,500 trout were checked as to sections where the fish were planted and where caught. Though definitely individualistic in their migratory tendencies, these fish had considerable inclination to wander. Data indicated that a plant of legal-size trout in the half-mile section adjacent to an inaccessible area on this stream would lose a minimum of 26 percent of its numbers to the latter area; in other words, more than one-fourth of these fish would be lost to the fishing public. As planting allotments for this type of stream may average some 200 pounds per mile, the loss would be a minimum of 26 pounds or approximately 100 trout of nice catching and eating size.

By making no plants within one-half mile of an area where fish would be lost or inaccessible, the State is able to save for its fishermen, in this type of stream, 10 creels of 10 trout each which have cost upwards of $1 per pound to produce and distribute. Multiply this by the hundreds of similar situations throughout the State, and it becomes evident that a bit of prying into the migratory tendencies of stocked trout has resulted in more fish for more creels.

RESULTS FROM RESEARCH AT GREAT SLAVE LAKE

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Great Slave Lake in northwestern Canada is the fifth largest North American lake. This lake is smaller than the three upper Great Lakes and smaller than Great Bear Lake, which is also in northwestern Canada. Until 1945, Great Slave Lake had never been exploited commercially.

Starting in 1944, Dr. D. S. Rawson, working under auspices of the Fisheries Research Board of Canada (scientific arm of Canada's Department of Fisheries), explored the fisheries potential of the lake. As a result of his findings, commercial fishing for lake trout (Cristivomer namaycush) and lake whitefish (Coregonus clupeaformis)—the only commercially important species in the lake—began in 1945.

In 1946 a detailed scientific study of the commercial fishery and of the fish it exploited was begun by the Central Fisheries Research Station of the Fisheries Research Board of Canada. The results of this research were very useful in 1948. A highway completed in that year linked Great Slave Lake with the rest of Canada by road for the first time. Previously the only practical way to get fish from the lake to the markets had been to freeze the fish at the lake and keep them frozen while moving them about 500 miles by river to the nearest railhead. Only one fish company had chosen to invest the capital needed for such an operation, and as a result the lake was producing less than the amount that Dr. Rawson had suggested as a reasonable crop. The opening of the new road made it possible for fish companies with much less capital to operate, and several were preparing to establish themselves on the lake. There was, therefore, the question of how heavily the lake should be fished.

Because of the scientific study begun in 1946, the answer was at hand. The data showed that, though most of the fishing up to 1948 had been done in a very limited area, there had been no adverse effect on the limited fish populations so exploited. Tagging showed little movement within the lake. The unexploited parts of the lake were known to be about as productive as the heavily exploited area. All the facts indicated that Great Slave Lake would yield at least 9 million pounds per year indefinitely in addition to the fish required by the local people for their own use. Fishery regulations designed to keep maximum catch at about this figure and to distribute fishing pressure over the whole lake were put into effect. The fishery has produced an average of slightly less than 9 million pounds each year since 1948.

For about 3 years the new regulations were strongly assailed from time to time—mostly by groups concerned with the welfare of local Indians, but to some extent also by the fishing industry--on the grounds that the lake was being overfished. The scientific study had been continued, and every attack on the regulations was met with overwhelming scientific evidence that showed the attacks to be groundless. No changes were made in the regulations except for minor adjustments suggested by further research. Time has now shown the wisdom of permitting the increased rate of exploitation.

Only the results of research made it possible to continue the predetermined rate of exploitation. Without the scientific information, there is no question but that pressure from various sources would have forced drastic reduction in the level of exploitation and perhaps complete cessation of commercial fishing. Thus research was solely responsible for the harvest of a fish crop of several million pounds that otherwise would have served no useful purpose.

To the scientists concerned, the real value of the research at Great Slave Lake lies in its general application, especially as no other major North American lake has been studied intensively from the start of commercial exploitation. However, forgetting the more desirable birds in the bush, the bird in the hand is still worth mentioning: at the very least, 4 million dollars' (perhaps more than 10 million dollars') worth of fish produced since 1948 as the result of the research project alone.

REVIEW

FISHERY SCIENCE: ITS METHODS AND APPLICATIONS

George A. Rounsefell and W. Harry Everhart
John Wiley and Sons, New York, 1953, ix + 444 pp., illus. $7.50

Rounsefell and Everhart have produced a first--the first successful attempt to present a textbook with a claim to comprehensive treatment of what might better be called the science of fishery management. "The real purpose," the authors say in the preface, "is to present the problems that confront the administrator, the research worker, and the student, and to show how to go about solving them."

Oddly enough, Part XI, Problems, comprising chapter 25, is the last section of the book. In it seven major categories of problems are presented: abundance predictions, natural balance, environmental measurements, genetics, role of nutrients, estuarine ecology, and interspecific relations--all cited as fields in which knowledge is notably deficient. Yet in all the preceding 24 chapters, devoted chiefly to an explanation of methods of solving problems, the standard problems facing research worker and administrator are forcefully indicated and not always solved.

"Fishery management," the authors say, "is the application of scientific knowledge concerning fish populations to the problems of obtaining the maximum production of fishery products, whether stated in tons of factory material or in hours of angling pleasure. This knowledge concerns the dynamics of fish populations, their environment, and their responses to variations in their environment, including exploitation by man." This is an extremely broad field, and the attempt to include even a synoptic treatment of the many topics in 25 chapters has necessitated a rigid selection of only the most significant.

The authors quite justifiably "offer no apologies for omissions," and the reviewer has no criticism of those topics selected for inclusion, but the brevity imposed by space has invited the charge of superficial treatment of some subjects which have suffered by too great condensation. Part II, Natural Populations, comprising 5 chapters totaling 84 pages, suffers from this difficulty. A study of populations and their fluctuations, population dynamics, is a quantitative science requiring a fairly advanced grade of mathematical treatment. For the average biologist the illustration and explanation of methods for separating and identifying populations, measuring the effects of exploitation, or estimating population size will be quite unintelligible unless he has had considerable training in statistics. If the authors had not assumed so much knowledge on the part of the reader and had shown a little more tolerance of ignorance, a little more sympathy with the beginner, they would have made a complex subject more understandable and thus would have encouraged both fresh-water and marine fishery investigators to master and use these valuable tools of research.

Part III, Fish Ponds; IV, Fishing Gear; V, Protection Against Hazards; VI, Improvement of Habitat; and VII, Tagging of Fish, are simple, straightforward, highly readable, descriptive accounts of a large segment of equipment and practices concerned with fisheries. In most of the chapters, brevity is again the chief

fault, although the "gadgetry" of fish tagging seems unduly emphasized by the detail in chapter 16.

Part VIII, Age and Growth, exhibits an abrupt change of pace. Chapter 18, How To Determine Age, is condensed but adequate, whereas Chapter 19, Growth, bogs down in mathematical formulae and in confused and confusing physiological explanations. The authors could hardly expect to elucidate autocatalytic concepts of growth in the 26 lines devoted to that topic.

The remaining sections march on with an assurance and a charm that are most pleasing. The chapter on fishery statistics is purely descriptive of a subject very familiar to the senior author. The chapter on stream and lake surveys obviously is home ground for the junior author; it is clear, detailed, and practical. The chapter on management techniques is good but too short, a comment that applies equally to the following chapter on artificial propagation as a tool of management.

The penultimate chapter, however, appeals to the reviewer as the cream of the lot. The authors present a discussion of fishery regulations and their effects, a subject which for some strange reason has had little attention from competent scientists. It is straightforward, thoughtful, sound, frank, courageous, and stimulating. Both scientists and administrators should study it.

Nearly every chapter includes a list of literature cited in the text, a list which should be studied by the serious student. The appendix contains a glossary and a helpful list of organizations and the journals that they publish in the fishery field "to aid students and others in library browsing." There is an index. The illustrations are well produced and well selected (although it is odd to see a "blueback trout" among the characteristic game fishes in the single colored plate presented), and the publishers used good paper and good type in executing a good job of bookmaking.

In their first attempt, Rounsefell and Everhart have set a high standard in textbook writing for a field in which a unified account of the science was badly needed. The book should prove most useful in class instruction for upper-division college courses and stimulating and helpful for conservation workers generally.

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RESEARCH FOR LARVICIDE IN LAMPREY CONTROL

One phase of the research program undertaken by the U. S. Fish and Wildlife Service in the near future will be concerned with discovering some means of destroying sea lampreys that have already reached the larval stage in the streams. The imperative need for an effective larvicide was emphasized in the summer of 1953, when more than 1,600 spawning-run lampreys were captured in the 10 control structures which were operated during part of the spawning season. The presence of spawning-run lampreys in as great number as this indicates that streams of Lake Superior may even now be well seeded with larval lampreys. As these ammocoetes spend 4 to 5 years in the stream bottom, it is quite possible that during the next few years the number of parasitic-phase lampreys occurring in Lake Superior--the last of the great Lakes to have a good-sized stock of lake trout--may be sufficient to bring disaster to the lake trout fishery even though any further spawning of the sea lampreys is prevented.

CLEARING HOUSE

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No. 111. 38 pp., illus.
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Pub. Health Bib. Ser. No. 8
66 pp., illus. 1953. 30¢.

Selected bibliography of publications on industrial wastes relating to fish and oysters.--W. M. Ingram and Peter Doudoroff, Public Health Service.
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Superintendent of Documents
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28 pp., illus. 1953.
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Culture and diseases of game fishes.--H. S. Davis.
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University of California Press
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166 pp., illus. $2.
September 1953.
Ragland Studio & Litho Printing Co.
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*The New York State fish hatchery feeding chart.--C. R. Deuel, D. C. Haskell, D. R. Brockway, and O. R. Kingsbury.
Fish. Res. Bull. 3
61 pp., illus.
3d ed., 1952.
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Albany, New York.

*Designed for trout hatchery management exclusively and available only to those engaged in trout propagation work.

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